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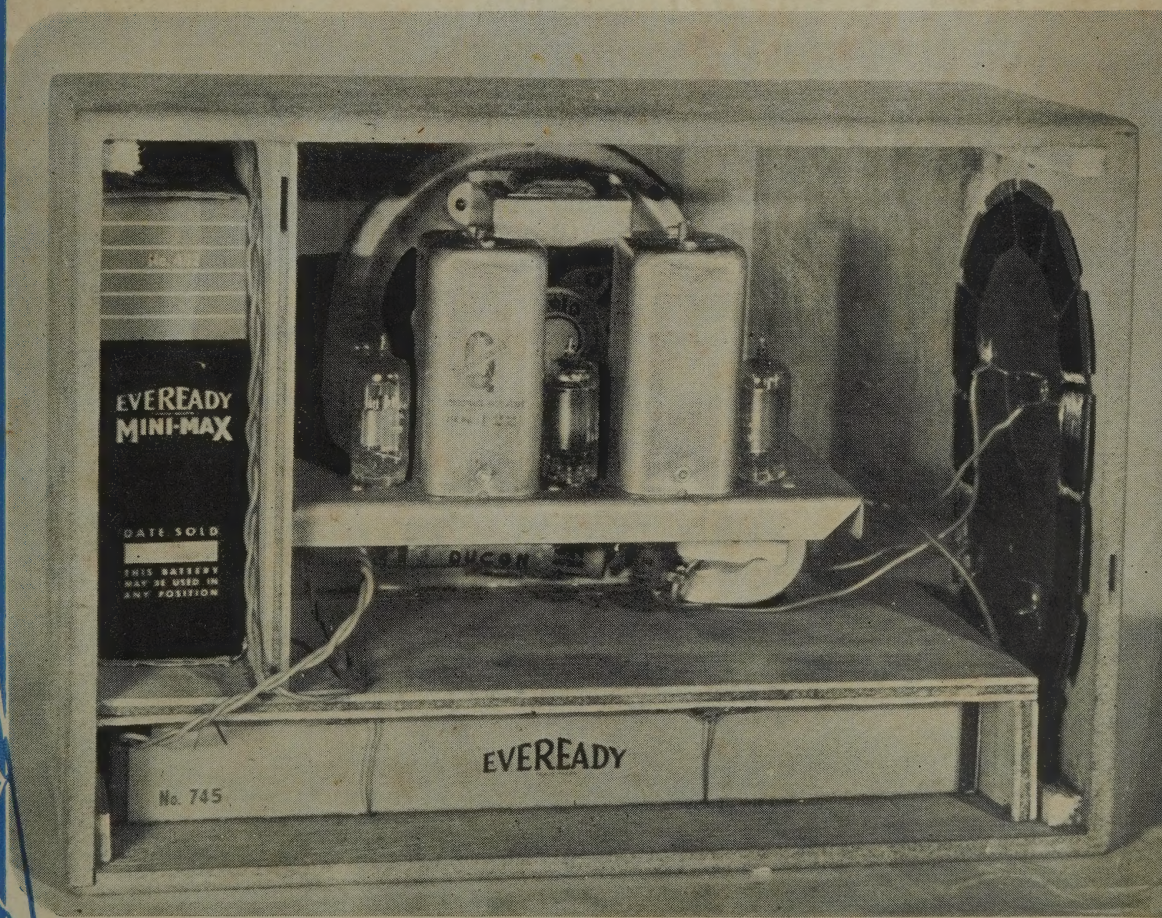

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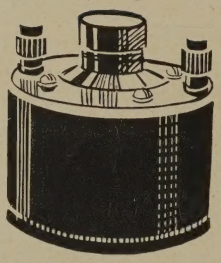

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RADIO and ELECTRONICS

Vol. 2, No. 9 December 1st, 1947

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OUR COVER

OUR FRONT COVER is an illustration (rear view) of the Radel Portable Four described in this issue.

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GUY E. MILNE
ELECTRONIC TECHNICIAN

NEGATIVE FEEDBACK IN TRANSMITTER CIRCUITS

The subject of negative feedback in audio amplifiers is one which has received a great deal of attention in recent years, both from the theoretical and practical points of view, so that it can now be regarded as standard practice in cases where distortion must be reduced to a low figure. Not so well known, however, is the application of the same principle to transmitting circuits in such a way as to improve the characteristics of modulated R.F. amplifiers.

Where high-level or plate modulation is used, particularly with triode R.F. amplifiers, sufficiently good performance for most purposes may be obtained by ensuring in the first place that the speech amplifier and modulator stages themselves have low enough distortion at full rated output, and by adjusting the excitation, bias, and loading of the class C_2 modulated amplifier.

This is because the class C_2 plate-modulated triode R.F. amplifier is essentially a linear device when it is properly designed and operated, but there are many cases where an attempt to get something for nothing has normally to be paid for in accepting a less linear modulation characteristic, with a resultant rise in distortion at high percentages of modulation, or alternatively a reduction in maximum modulation percentage, in order to keep distortion within bounds.

Within this category come all forms of low-level modulation such as the control-grid modulation of triodes, tetrodes and pentodes, and the suppressor-grid modulation of pentodes. In these systems there is a gain in the form of a greatly reduced power requirement from the modulator, which represents a decrease in cost. It is offset, however, both by decreased efficiency in the modulated stage and by higher distortion due to nonlinearity in the modulation characteristic.

Various schemes have been put forward which largely remove the first of these disadvantages; notably there are the high-efficiency grid modulated systems due to Doherty, and to Woodyard and Terman. These systems are unfortunately complex to apply and difficult to adjust, so that their success as an economic proposition is confined to high-powered equipment.

With low-powered transmitters, however, efficiency of the modulated stage is not always a prime consideration, and in this case the greatest objection to the low-level modulation systems is their non-linearity.

It is under these circumstances, therefore, that negative feedback can be applied to the modulation system with greatest effect. Briefly the scheme is to rectify a small portion of the modulated output of the transmitter, thus re-deriving the audio or other modulation frequencies. These are then applied to the audio system at any convenient point, in such a phase that the feedback is negative. When this is done, all the advantages normally thought of as applying only to feedback round audio amplifiers are obtained for the modulated stage, that part of the audio system which is within the feedback loop and any R.F. amplifiers which may follow the modulated stage.

Thus, any distortion due to a non-linear modulation characteristic is reduced in proportion to the amount by which the feedback reduces the gain of the modulator system. Similarly, any noise—microphonics or hum—introduced in any part of the circuit within the feedback chain is reduced in the same proportion. Unlimited possibilities exist, too, for modifying the frequency response of the whole system by the inclusion in the feedback chain of frequency discriminating networks.

Of course, the scheme outlined above is not itself a way of getting something for nothing, as its advantages have to be paid for by providing extra gain in the audio voltage amplifier channel, and by care in design, to ensure that oscillation does not occur due to undesired phase-shift in the feedback loop, but for the results that may easily be achieved, the price is a small one.

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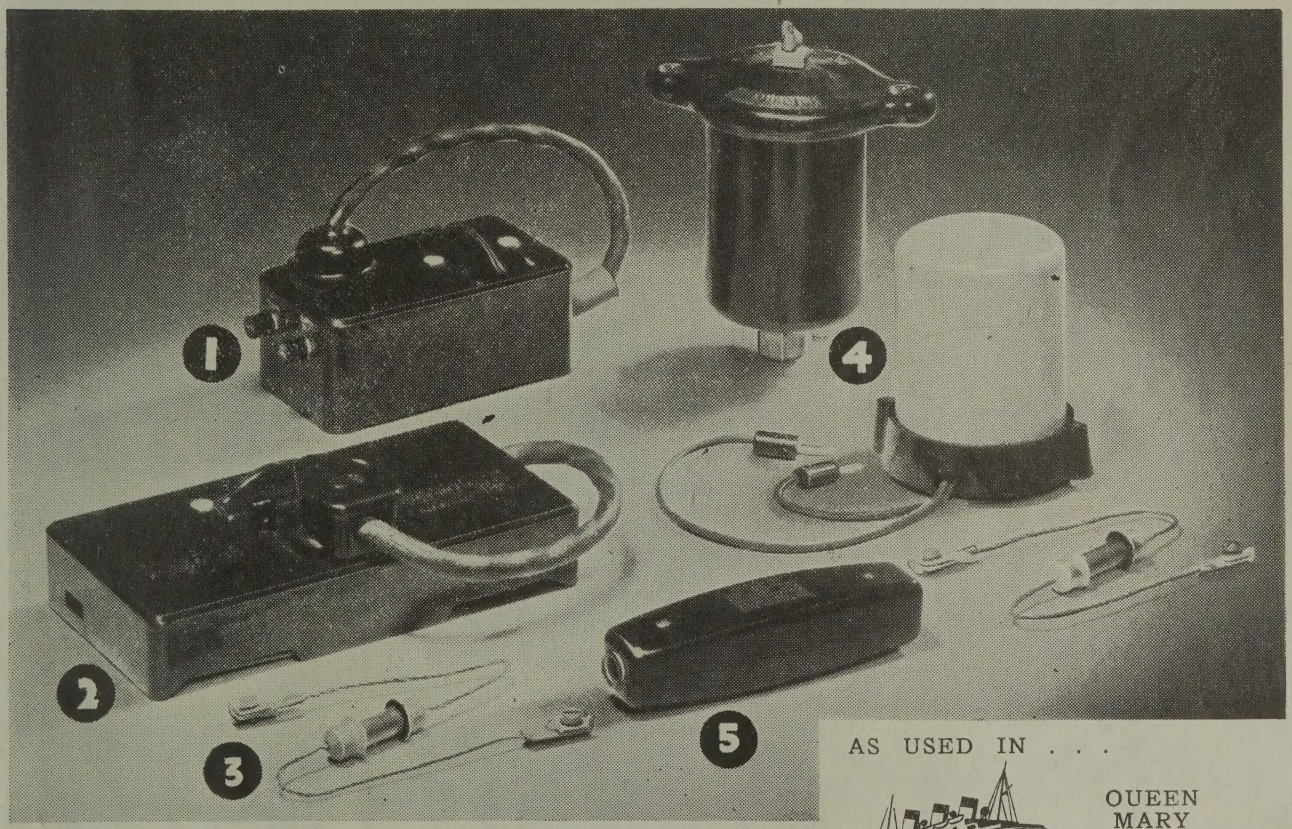

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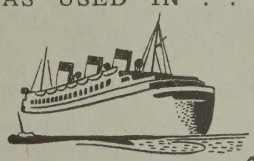

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ELECTRONICS IN METEOROLOGY

THE FOURTH OF A SERIES OF ARTICLES DESCRIBING ELECTRONIC DEVICES THAT ASSIST THE MODERN METEOROLOGIST

By R. E. EWING, B.Sc.

Previous articles have described the various types of frequency variation radiosondes, and it now remains to describe the other main principle used in radiosonde design, namely the chronometric principle.

The chronometric principle, as its name implies, uses time as the basis by which the meteorological variations control the radio transmission. This principle was originally worked out by Olland in 1875 and is usually known as the Olland cycle. It can best be described by reference to the diagram shown in Fig. 1. Suppose an arm OA carrying an electrical contact at A rotates at a uniform speed about O. If there is only one fixed contact R on a circle with O as centre, contact will occur at regular intervals depending on the speed of rotation of the arm OA.

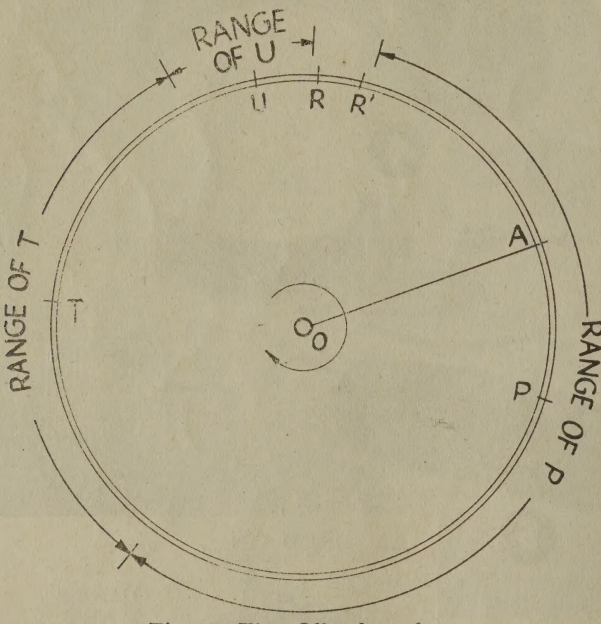


Fig. 1. The Olland cycle.

If now another contact P is introduced the position of which on the circle is controlled by a pressure sensitive element, the time interval between the fixed contact and the movable contact gives a measure of the pressure. If the circle is divided into three sectors, and movable contacts P, T, and U, controlled by pressure, temperature and humidity sensitive elements respectively each operate within one sector, measurements of these parameters can be obtained by observing the sequence of time intervals. When more than one moveable contact is used in the cycle two fixed contacts (R, R^1) are provided so that the position of these reference contacts can always be identified by the invariable time interval between them.

A system such as shown in Fig. 1 is mechanically awkward, and in most chronometric radiosondes in use to-day, the rotating arm has been replaced by either a rotating helix or equiangular spiral as shown in Fig. 2 (a) and (b) respectively. The contacts attached to the meteorological elements (only one element is shown in Fig. 2) and the reference contacts each touch the helix once in a revolution,

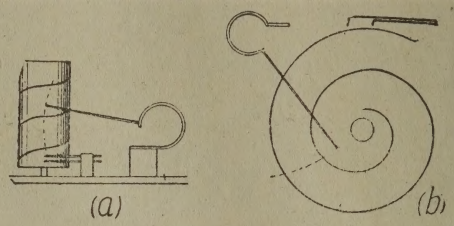


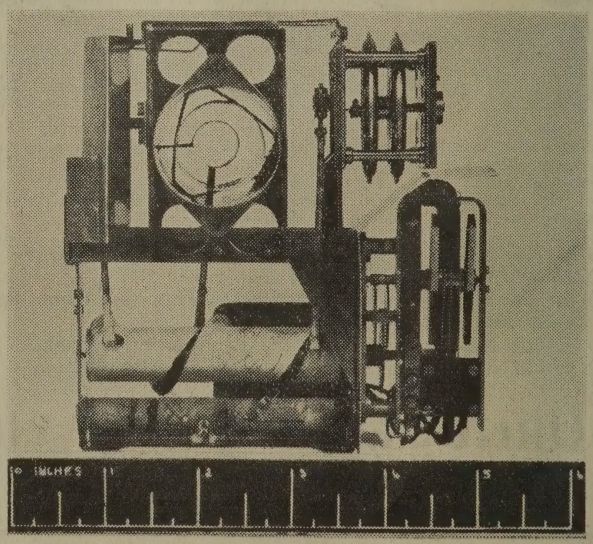
Fig. 2.

the time interval between the resulting signals being a linear function of the height of the meteorological contact above the base. The advantage of this scheme is that any or all of the meteorological elements may occupy more than one complete cycle, and can indeed extend over any number of cycles, except there is a limit to the amount of overlapping that can be tolerated.

Fig. 3 shows the meteorological portion of the British chronometric radiosonde, and the helix together with the contacts attached to the meteorological elements can be clearly seen.

The accuracy of all these arrangements depends chiefly on the uniformity of the speed of revolution over the entire cycle from one reference contact to the next, while the precision of the measurements will depend on how small a part of a revolution can be distinguished.

Below: Fig. 3.



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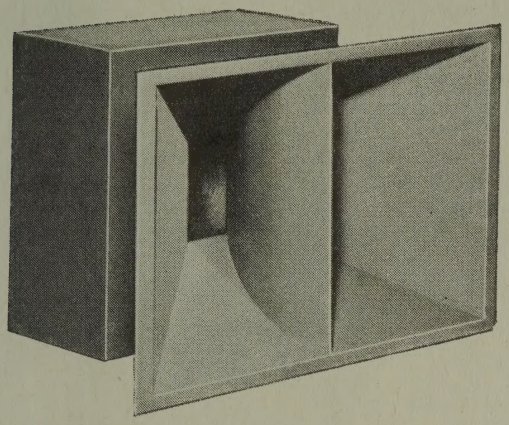

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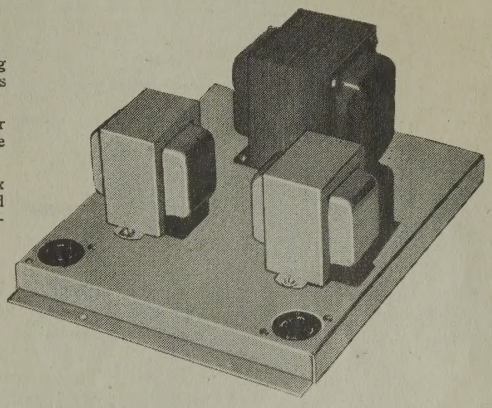

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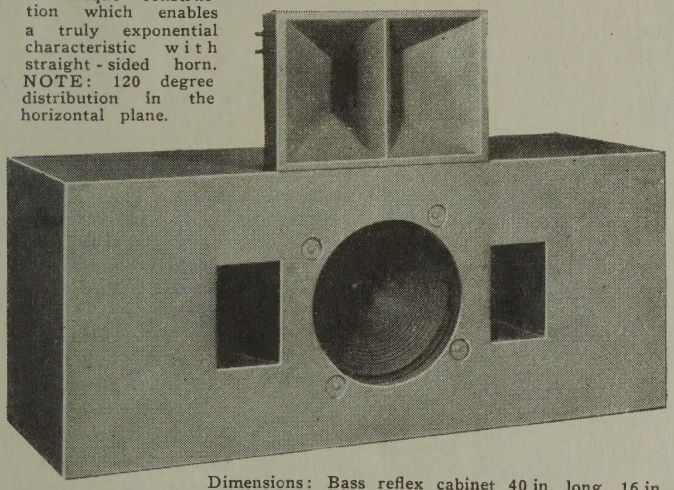

CROSSOVER NETWORK: This is a definitely new design which has the great advantage of being low cost production and for selling purposes therefore a more economical proposition than has ever been put on the market before. It gives a superior result at lower cost. This unit has been submitted to independent organisations for check and the results of the findings are graphed below. Authorities—The Laboratory of Beacon Radio, Ltd., and Mr. H. A. Whale, M.Sc., Grad.I.E.E. The whole system is small enough to be placed in the base of a low-boy console.

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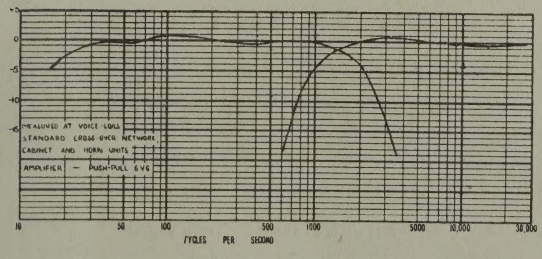
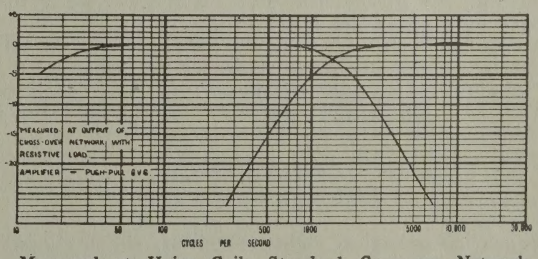


Measured at output of Crossover Network with resistive hood. Amplifier—Push-pull 6V6.



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These difficulties are overcome in the modern chronometric radiosonde by the use of a small electric motor for the drive. The speed of this motor can be controlled by a sustained tuning fork, thus giving a continuous steady rate of revolution, or alternately the motor can be arranged to give an independent series of pulses which can be transmitted in addition

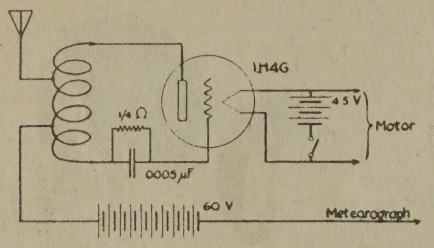

Fig. 4.

to the signals sent by the meteorological elements thus making it possible to ensure absolute synchronisation between the helix rotation and the ground recorder.

The radio transmitter used with a chronometric radiosonde can be of the simplest form, and usually only one valve is employed. The circuit diagram of the transmitter used with the Canadian chronometric radiosonde which operates at a frequency of 65 megacycles per second is shown in Fig. 4.

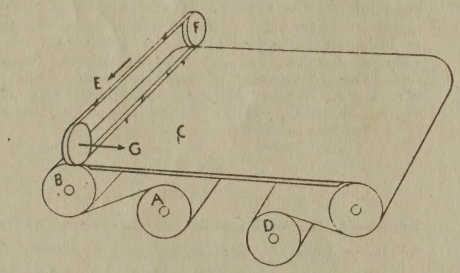

Fig. 5.

The ground equipment used with any chronometric radiosonde consists of a suitable radio receiver the output of which is fed to a relay which operates a chronograph of special design.

In the Canadian chronograph a roll of wax-surfaced record paper 11 inches wide is fed at a speed of ½ inch per minute from a roll A over a drum B on to a horizontal table C, being finally rerolled at D. (See Fig. 5.) Just above the surface of the paper travels an endless chain, carrying four styli, and so dimensioned that the distance between the styli is equal to 4/3 of the pitch diameter of either of the sprockets F. The axes of these sprockets are horizontal, and the entire assembly is mounted on a frame which can be displaced by an electromagnet through about 1/16 inch in the direction indicated by the arrow G, and returned by a spring. This electromagnet is controlled by the relay operated by the receiver.

When no signal is being received, the styli pass across the paper in constant succession, taking about 13 seconds (the time of the cycle in the Canadian radiosonde) to travel about 6 inches, the succeeding stylus coming on to the chart before the preceding one has left, and each drawing a fine straight line nearly at right angles to the direction of motion of the paper. Because of the constant motion of the paper, these lines are about ⅛ inch apart. Each signal produces a rectangular jog in the line, the beginning of the jog being an accurate indication of the time at which a contact was made on the radiosonde.

The speed of the styli can be regulated with

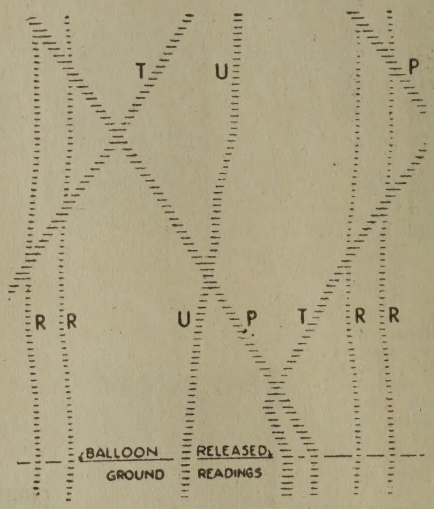

Fig. 6.

accuracy, in order to synchronise their travel with the length of the radiosonde cycle. The phase relation between the two motions is chosen so that the double reference contact comes in the interval between the entry of one stylus and the lifting of the preceding one, and therefore the double line of jogs shows at both sides of the record. The appearance of the record is shown schematically in Fig. 6, in which the lines produced by the undeflected styli have been left out.

The times of the pressure, temperature, and humidity contacts are measured as a fraction of the length of the cycle in which they occur, and by referring to the calibration data for the particular radiosonde used, the actual pressure, temperature, and humidity encountered during a flight can be computed.

This article concludes the review of the present state of development of radiosonde equipment. It is

(Continued on page 55.)

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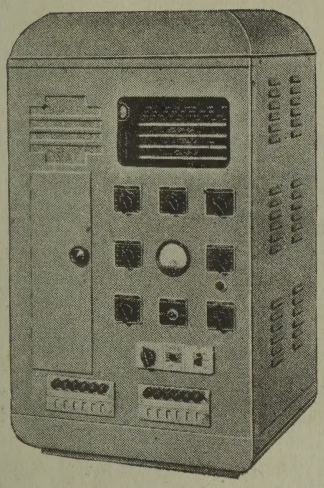

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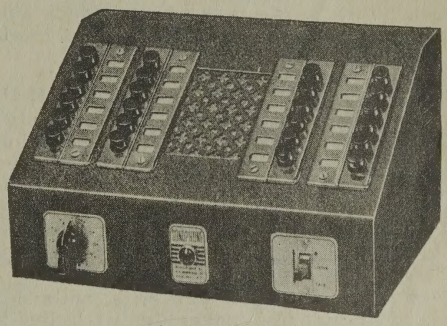

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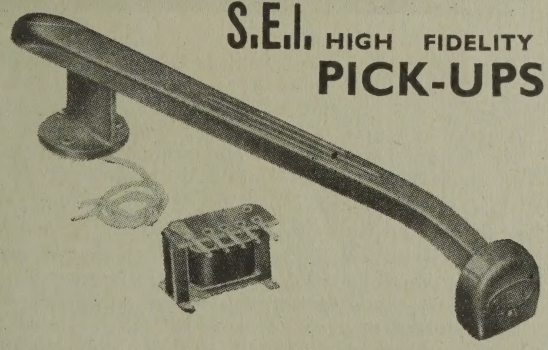

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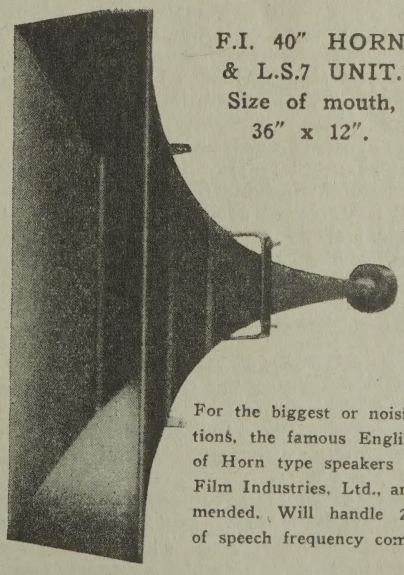

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THE RADEL PORTABLE FOUR

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We have accordingly designed two receivers, of which this is the first, one of which should suit the taste of most people who need a portable set for broadcast band only.

SIZE AND TUBE LINE-UP

In this receiver, the new miniature tubes have been used in order to conserve space, but no attempt has been made to evolve a super-compact design, since miniature components other than valves are rather difficult to come by. For instance, not everyone may be able to obtain miniature I.F. transformers. Again, it was thought desirable to use the larger types of miniature battery, so that battery replacements would not be a nuisance, in spite of the fact that this makes the set larger than it otherwise could have been. The circuit has been arranged to use either 45 or 67.5 volts H.T., so that the slightly better performance conferred by the latter can be obtained, if so desired.

In short, the set has been made as flexible as possible, without making it too large or heavy, so that it may fit in with as many ideas as possible that readers may have on what are the most desirable features in a portable. The tubes used are a 1R5 oscillator-mixer, a 1T4 I.F. amplifier, a 1S5 second detector, A.V.C. and first audio stage, and a 1S4 output stage.

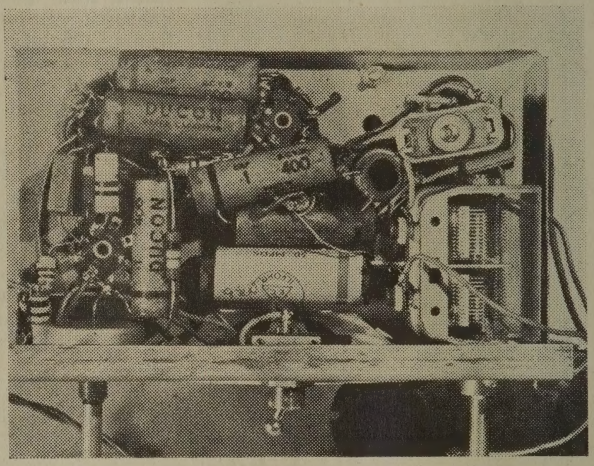
This arrangement gives ample gain for all local reception purposes. It is not intended, for instance, that this set should be able to give full volume from stations 300 miles or so away, for, since most listening is to local stations, such a requirement seldom arises. Nevertheless, 3YA may quite easily be read in Wellington at medium volume, which gives some indication of the set's sensitivity, which is ample for all local reception.

CIRCUIT DETAILS

The circuit is shown in the accompanying diagram. A tuned loop is used, directly connected in the mixer grid circuit. The loop also has a single-turn primary winding to which an external aerial may be attached if desired.

On account of the unusual electrode arrangement of the 1R5 oscillator-mixer tube, the oscillator circuit is slightly unusual, too. The screen, while at ground potential for I.F. (which is 465 kc/sec.) acts at the same time as the oscillator plate, so that we have the screen connected to the low-potential end of the first I.F. transformer primary, and the oscillator tickler in series with the I.F. winding. This scheme is the one recommended by R.C.A. for use with the 1R5, and was found to give no difficulty at all. Since the only trouble likely to be encountered with these miniature mixers is that of lack of oscillation, this shows how easy the 1R5 is to apply in spite of its unusual arrangement. V_2, the 1T4 I.F. stage, is quite conventional in all respects.

A.V.C. is applied both to the mixer and I.F. stages, and is sufficiently effective to hold the set down on the strongest local signal likely to be encountered. C_8, as well as acting as the A.V.C. filter condenser, bypasses the earthy end of the tuned loop winding, just as is done with a normal R.F. or aerial coil secondary.



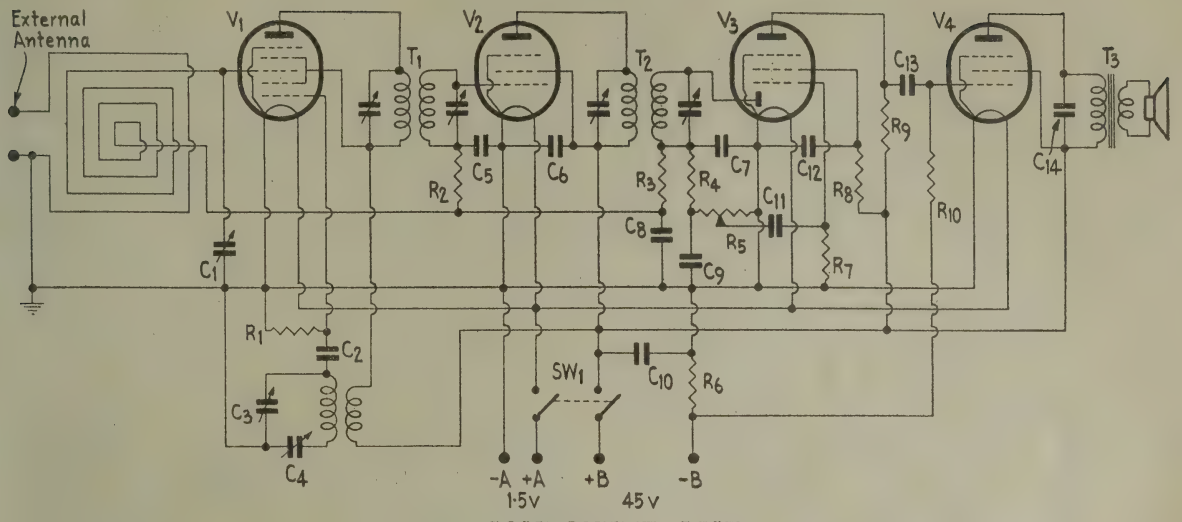
In spite of the apparent lack of a minimum bias on V_1 and V_2, there is a small negative bias of about a volt applied to their grids by the action of contact potential in the diode detector. The tubes are designed to run with maximum gain at zero bias, so that this scheme has no disadvantages.

In a similar way, V_3, the audio amplifier stage, is provided with grid-leak bias through a 10-megohm grid resistor, R_7. This is a much better way of biasing small battery tubes which require less than 1.5 volts, than attempting to use a voltage divider in conjunction with a bias battery. It has been proved, also, to introduce a very slight amount of distortion, even when compared with other biasing systems for this type of tube.

The output stage, V_4, is a 1S4, which has a rated power output of 65 milliwatts with 45 volts on the plate and screen, and 180 milliwatts with 67.5 volts. We will have more to say on this point later. The condenser, C_{14}, connected across the output transformer primary, is by way of a fixed tone control, limiting the high-frequency response to a range suitable when taken in conjunction with the inevitably limited low-frequency response obtained from a miniature speaker in a small cabinet.

It is necessary, also, for another very important reason—namely, to bypass any I.F. signal that may be passed by the audio stages. Depending on the exact lay-out of the wiring, the omission of C_{14} may cause instability.

Bias for the output stage is obtained across R_6, through which the whole plate current of the set passes, this scheme being known as back-biasing.



COMPONENT LIST

C_1, C_3 = 2-gang condenser.
C_2 = 50 mmfd.
C_4 = 600 mmfd. padder.
C_5, C_8 = 0.05 mfd.
C_6, C_{12} = 0.1 mfd.
C_7, C_9 = 100 mmfd.
C_{10} = 8 mfd. 50v. electro.
C_{11}, C_{14} = 0.002 mfd.
C_{13} = 0.0005 mfd.
R_1, R_2 = 100k.
R_3, R_{10} = 2 megs.
R_4 = 50k.
R_5 = 1 meg. pot.
R_6 = 500 ohms.
R_7 = 10 megs.
R_8 = 3 megs.
R_9 = 1 meg.
T_1, T_2 = 465 kc/sec. I.F. transformers.
T_3 = output transformer 8000 ohms to V.C.
Sw_1 = D.P.S.T. on/off.
V_1 = 1R5.
V_2 = 1T4.
V_3 = 1S5.
V_4 = 1S4.

It is a form of cathode bias which can be used with filament-type tubes, whereas ordinary cathode biasing cannot be used without considerable difficulty. It will be noted that this system entails the use of separate leads for connecting A — and B —, which cannot be joined together at the battery. Should they be, there would be no bias voltage developed for V_4, which would not do the tube any good, and at the same time would cause very poor quality, and reduced battery life, since the output stage would be drawing much more than normal plate current.

CONSTRUCTIONAL FEATURES

Diagrams are given here for the chassis and for the inside dimensions of the cabinet. Outside dimensions of the latter have not been specified, since these will depend upon the thickness of the wood used. Needless to say, a metal cabinet cannot be used to house the set, since the loop is mounted inside the cabinet, and complete shielding hardly improves its signal pick-up! These diagrams, together with the photograph on the front cover of this issue, give a good idea also of the electrical lay-out of the set.

The cut-out on the chassis is made to accommodate a 5 in. speaker. This has been used because, in agreement with our decision not to use midget I.F. transformers and so on, the use of a smaller speaker would not enable any reduction in the size of the complete set. Thus, the height of the set above the chassis is already determined by the standard I.F. transformers, so that a 5 in. speaker may be used without increasing the overall height of the cabinet. In general, a 5 in. speaker is an advantage, since it is usually found to be more sensitive than a 3 in. one. This is a very important point where the available power output is severely limited, as here, and the greatest possible sound output is essential in spite of it.

The mounting of the batteries in their compartments can be seen clearly in the photograph, as can the position of the loop, which is mounted on the side of the cabinet remote from the B battery compartment. There is ample room left between the loop and the chassis so that the proximity of the latter will have a negligible effect on the loop's performance. This makes the cabinet slightly longer than it might otherwise be, but the extra length is worth having for the extra loop efficiency which it imparts.

MOUNTING THE CHASSIS

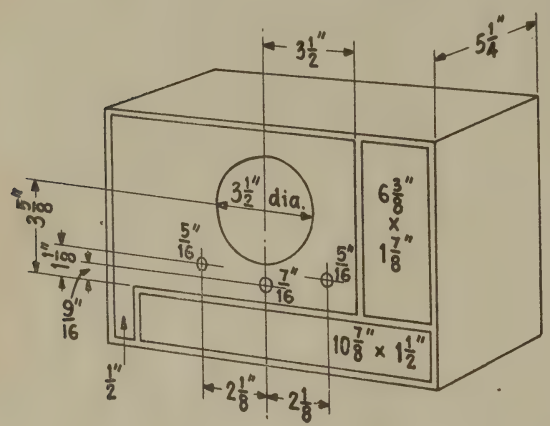
The chassis has no mounting lugs whereby it is screwed down to the cabinet. Instead, the speaker is firmly mounted on the chassis by means of two of its mounting holes, and the other two are used to hold the speaker and chassis, as one unit, to the front of the cabinet.

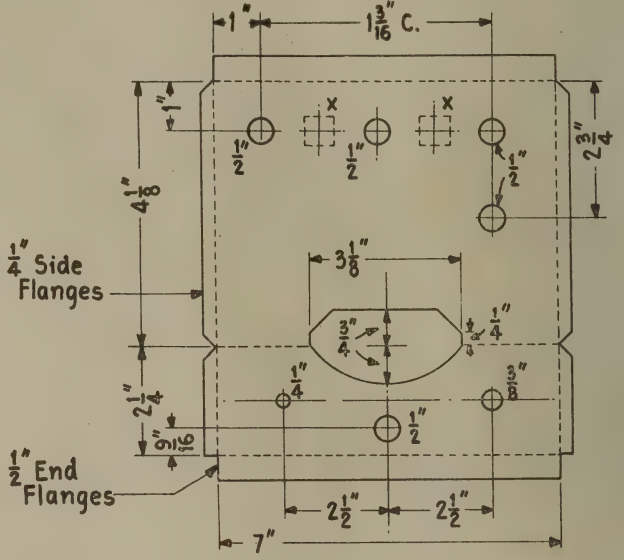
This is quite rigid, since the shafts of the tuning condenser and volume control keep the chassis from moving as well. The chassis has no back or sides, because it is so light that their support is unnecessary and their absence makes it much easier to fit the small parts into place.

GANG CONDENSER

This is a midget two-gang component which can be seen mounted on the front of the chassis in the

underneath photograph. This particular type is provided with built-in trimmers, for which holes are bored so that adjustment can be done through the top of the chassis. Unfortunately, the shaft provided is not long enough to reach through the front of the cabinet far enough, so that a plain bush and a piece of extension shaft (a small piece cut from a potentiometer shaft will do) have to be fitted. The dial is made in the form of a simple plate, attached to the front of the cabinet, in conjunction with a small pointer-type knob.





45 OR 67.5 VOLTS

The B battery shown in the photograph is the larger type of "minimax" 45-volt battery. There is also a smaller and lighter type which has 67.5 volts and which can be used instead if greater power output is required. Using this battery, there will be a slight increase of gain, but the biggest advantage it confers is that of 180 milliwatts power output—almost three times that available when only 45 volts is used. The advantage to be gained is one of greater undistorted output power solely, and is a great help if one cannot be quite close to the set, or if a certain amount of extraneous noise has to be overcome. The 60 milliwatts from 45 volts of B battery is sufficient for normal purposes, but the 67½-volt battery should be used if the utmost in performance is required.

LAY-OUT OF PARTS

This can be quite readily seen from the underchassis photograph. The only coil is that for oscillator, and the padder condenser can be seen close to it, making the leads for the oscillator circuit short and direct.

It is unlikely that oscillation of the I.F. stage will be experienced. If it is, it should be sufficient to earth the central metal rivet on the valve socket.

ALIGNMENT

The alignment of this set is no different from that of any broadcast superhet., since there are aerial and oscillator trimmers and oscillator padder to be adjusted in addition to the I.F. trimmers. If permeability tuned iron-cored I.F. transformers are used, as in the original model, care should be taken not to cover up the bottom adjusting screw when wiring in the resistors and condensers, as nothing is more annoying than having to re-wire some of the set in order to line it up.

The oscillator trimmer should not be touched until the I.F. transformers have been aligned to exactly 465 kc/sec. If no signal generator is available, it is good practice to leave the I.F. trimmers at their original setting and perform the oscillator and aerial trimming first. This is because the I.F. transformers are always adjusted to frequency at the factory. Thus, only minor adjustments should be necessary. If good results cannot be obtained by this means, the set should be taken to a serviceman to have the I.F. stage properly aligned.

In adjusting the R.F. end, the set should be tuned to the local station which has the highest frequency, and the aerial trimmer tuned for maximum output. Next, the set should be tuned to the lowest-frequency local station and the padder adjusted, step by step, the set being re-tuned with the gang condenser at each alteration of the padder, until the loudest signal is obtained.

With a portable set the best procedure is to turn the loop carefully until the point of minimum signal is found. This minimum is quite sharply defined, and is due to the well-known directional property of a loop aerial. It should always be used when lining up the set on an actual signal, because, if it is not, the action of the A.V.C. system makes it difficult to tell when maximum signal is achieved due to bringing the circuits into line.

The procedure recommended above is a good one for a set designed solely for local reception, since it ensures that best results will always be obtained on two of the local stations, and in that part of the band between them. Those parts of the band outside this range are of very little interest, so that misalignment due to not lining the set up at the exact frequencies of 1450 and 600 kc/sec., respectively does not matter.

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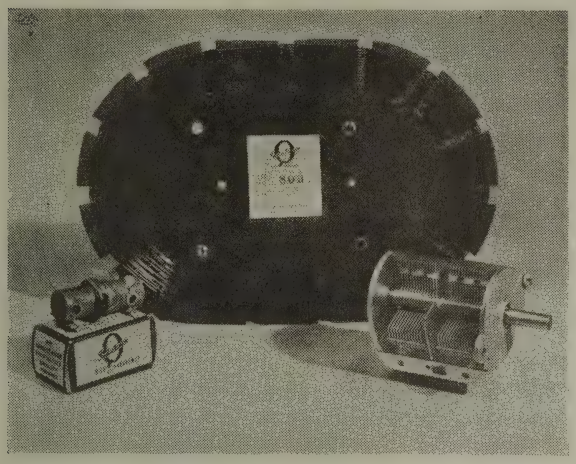
The Inductance Specialists new tunable loop, type 80, is designed especially for use in midget portables to combine maximum efficiency and compactness (so essential to successful portable performance). The Type 80 is available in both A and B series (gang capacities 420 and 360 mmfd. respectively), measuring 5 in. x 7 in. overall, and is wound on a special resin-bonded linen and paper bakelite frame. The special care given to the design and manufacture of this loop ensures excellent tracking with the oscillator—a point of even greater importance with portables than other receivers.



The recommended kit is as follows:—

Type 80 B (illustrated).
Type 51 BY (for 1A5 and 1A7 illustrated).
Type 122 permeability tuned I.F. transformers.
Type "R" Plessey two-gang midget condenser (illustrated).

When using an R.F. stage, the Type 15 or 25 coils should be used unless the stage is untuned. As the minimum chassis size is dependent on battery dimensions and other major components, Type 122 I.F. transformers ($1\frac{3}{8}$ in. square) are recommended to obtain increased efficiency.

It will be noticed that the midget "R" Plessey gang condenser is complete with trimmers, and also incorporates a celluloid dust-proof cover—an essential feature when plate mesh clearance is at a minimum and the condenser is subjected to considerable dust, fine sand, etc., which is unavoidable when the portable is taken to the seaside and on picnics.

Further details may be obtained from the manufacturers, Messrs. Inductance Specialists, 202 Thorndon Quay, Wellington.

* * *

THE "AUTOCRAT" CAR RADIO

The "Autocrat" car radio has made its appearance on the New Zealand market, and is now available for distribution.

Consideration has been given to sensitivity and ease of installation, and the attention paid to these important factors has resulted in a car radio which will give reliable performance under the most adverse conditions. A high efficiency adjustable aerial circuit is provided, which will give maximum performance on various types of aerials.

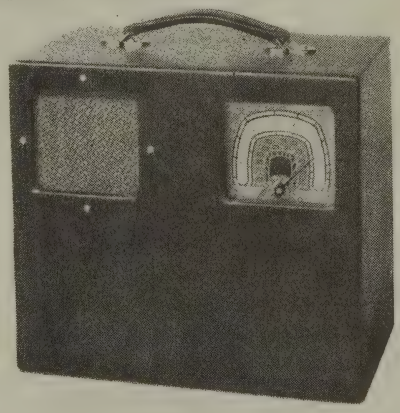
The receiver is constructed in two units each of very compact mechanical design. It comprises a 6SK7 R.F. stage, 6SA7 mixer, 6SK7 I.F. stage, 6SQ7 second detector, 6V6 output and 6X5 rectifier. The dial, which is built into the compact R.F. unit is chromium plated, and the scale has bold figures which are easy to see. A unique feature is the power supply and output tube assembled in the speaker housing. The speaker is a six-inch Rola Anisotropic Alnico P.M.

Every effort has been made to keep ignition noise at an absolute minimum, and in addition to filters being incorporated in the aerial and battery input circuits, the chassis is copper plated to reduce surface resistance. The battery current is 4.5 amps. for 6-volt circuits, and 2.5 for 12-volt circuits.

The receiver assemblies are finished in an attractive putty colour enamel.

Further details of the "Autocrat" may be obtained from the manufacturers, Messrs. Benson, Wills and Walker, 118 Victoria Street, Auckland.

THE R.S.C. PORTABLE KIT-SET is one which will give really excellent reception. Quality has not been sacrificed in order to save a few shillings and the kit comprises high quality components.



No. 1030

Measuring $12\frac{1}{2}$ x $11\frac{1}{2}$ x 6 it takes up about as much space as a small attache case. A five-valve circuit using "Q" coils, Plessey triple gang, R.F. converter, I.F. detector and audio, long-life batteries, one No. 745 A and two No. 702 B. "A" battery consumption .25 amp., "B" battery 12 milliamps. 5 in. Celestion permanent magnet speaker. Kit calibrated dial and built-in antenna with provision for external aerial if desired.

Kit, including cabinet less valves and batteries	£11 5 0
Set of valves	3 5 0
Batteries	2 4 6

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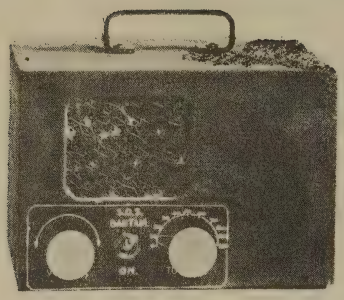

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1 x Midget Output Transformer
1 x ½ Meg. Volume Control
1 x Loop Aerial
1 x Cadmium Chassis, Punched
1 x Minimax 67½v. "B" Battery
1 x D.P.S.T. Toggle Switch
7 x Carbon Resistors
1 x 2-gang Polar Midget Condenser
1 x Padder Condenser
1 x 8 mfd. Electrolytic Condenser
1 x .1 mfd. Condenser
3 x .02 mfd. Condensers
1 x .01 mfd. Condenser
1 x .005 mfd. Condenser
2 x .0001 mfd. Condensers
1 x Midget Oscillator Coil
2 x "Wearite" Iron Core Midget I.F.'s
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4 x Peanut Sockets
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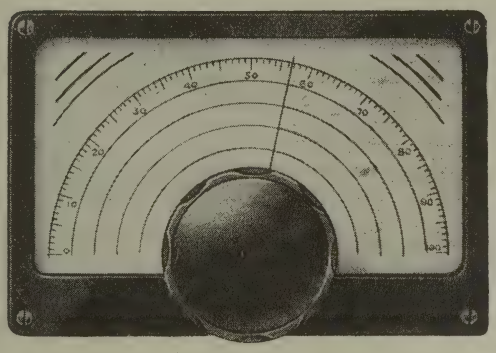
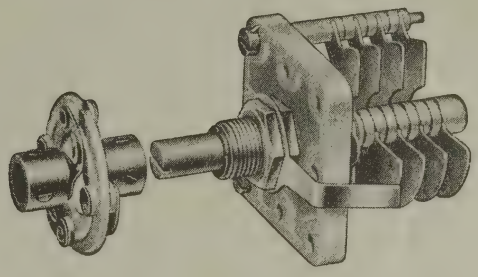


A most useful dial for all types of receivers, test oscillators and similar equipment. The dial escutcheon measures 6 in. long by 4⅛ in. wide. The scale is 5 in. across. The outer scale is marked 0-100 degrees and three other scale lines are provided for the user to mark in his own calibrations as desired. Two spare printed scales are supplied with each dial. A large fluted instrument knob is fitted. The drive mechanism has a reduction ratio of 10-1, is free from backlash and has a beautifully smooth movement. Cat. No. 598.

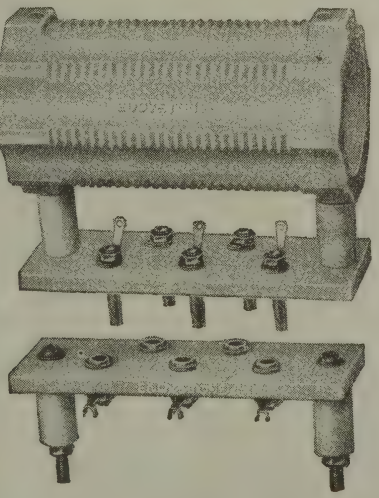
CONDENSERS



Eddystone also manufacture a complete range of variable condensers to suit the requirements of the short-wave experimenter, the professional radio engineer and the specialist trader. The condenser illustrated is an air dielectric condenser of 15 mmfd. capacity and is especially recommended for fine trimming and band-spreading purposes. Cat. No. 580.

FREQUENTITE COIL FORMER

Frequentite ceramic former for transmitting and similar apparatus. The former is 5 in. long by 2½ in. diameter, and may be mounted as illustrated or on Frequentite pillars. Spiral grooves take 26 turns of wire, up to 12 S.W.G. 14 holes are provided for leads and coil taps. The former is designed for coils covering 3 mc/s. upwards. Cat. No. 1090.



FREQUENTITE SUB-BASE

The sub-base is in Frequentite ceramic and is easily attached to the former by the two bolts and Frequentite pillars provided. It can be used separately as a base for self-supporting Inductances. Helically slotted power type plugs give positive electrical contact and even fitting to the ceramic is assured by lead washers. Leads are secured by heavy gauge tinned phosphor bronze self-locking soldering lugs. Cat. No. 1091.

FREQUENTITE BASE

The base is provided with Frequentite pillars for above chassis mounting. Heavy duty power type sockets give sound electrical connection with sub-base and lead washers on each socket ensure even fitting to ceramic. Leads are secured by heavy gauge tinned phosphor bronze self-locking soldering lugs. Cat. No. 1092.

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SOME NOTES ON THE CLASSIFICATION OF AMPLIFIERS

Textbooks on electronics are by no means unanimous in their definitions of the various classes of amplifier. This is caused partly by reason of the fact that the class of an amplifier alters practically all its properties, and each writer is usually more concerned with one property than another. Again, some writers themselves appear to have been confused by the implications of the subscripts 1 and 2 (and their omission), in conjunction with the three main classes A, B, and C. This is hardly to be wondered at, for no sort of standardisation seems to have occurred yet in the manner in which the subscript numerals are used. Everyone knows that the subscript 1 means "without grid current" and that 2 means "with grid current," but the loose practice of omitting the numerals altogether, on the tacit assumptions that no subscript also means "no grid current" in the case of class A amplifiers and at the same time means "grid current" in the case of class B and C amplifiers, appears to the writer to be the cause of much misunderstanding, and greatly to be deplored.

The fact is that the letters A, B, and C, and the subscripts 1 and 2, have their own meanings, quite irrespective of each other.

DEFINITIONS OF CLASS A, B, C, AND AB AMPLIFIERS

The four basic types of amplifier may be defined as follows:—

Class A:

A class A amplifier is one in which plate current flows at all points on the input voltage cycle.

Class B:

A class B amplifier is one in which plate current flows during approximately half the input voltage cycle.

Class C:

A class C amplifier is one in which plate current flows during appreciably less than a half cycle of the input voltage.

These definitions are simple, fundamental, and abundantly clear. It will be noted that not one of them makes any mention either of grid bias or of the presence or absence of grid current. These are important matters in connection with the three main classes, but **not by definition.**

Some writers tend to define the classes by means of rough specifications of the value of grid bias used, while some do even worse, and compound a mixture of this type of definition with the kind given above. This practice does much harm, because it tends to obscure the definition, particularly of class AB amplifiers. The correct definition of a class AB amplifier is as follows:—

Class AB:

A class AB amplifier is one in which plate current flows for less than the complete cycle of input voltage but for considerably more than a half cycle.

It should be pointed out that the four definitions given above are fundamental, in that they in no way specify the type of tube, the point to which it is biased, the amplitude of the input voltage, or anything containing any restrictive assumption whatever. In short they are completely general. The first three are illustrated in Figs. 1, 2, and 3, which show specific examples. Each shows the mutual characteristic of the valve, the input voltage waveform and the output current waveform, which is obtained by projecting values from the former on to the mutual characteristic. The arrows on Fig. 1 show the directions in which the time scale is assumed to increase. It should be noted that the scales of grid voltage differ on the three diagrams. This is purely for convenience, to keep the overall sizes of the three diagrams the same. Even a casual glance at these three diagrams shows that nothing in the illustration conflicts with the definitions already given.

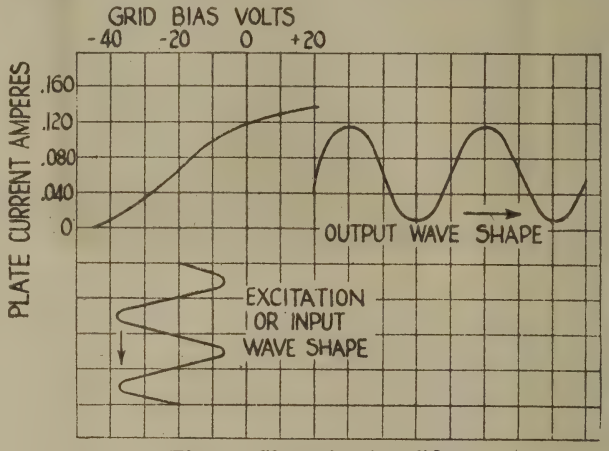

Fig. 1. Class A_1 Amplifier.

Apart from this fact, a number of points may be seen from the diagrams which, while important and typical of the classes illustrated, have no direct bearing on the definitions. For instance, in the class B case, Fig. 2, the standing grid bias is exactly at the cut-off value of 40 volts. Similarly, in the class A example the tube is biased near the centre of the straightest portion of the tube's characteristic, and in the class C case the bias is considerably greater than the cut-off value. However, these things do not make the amplifiers class B, class A, and Class C respectively. They are merely the result of the definition in that such conditions of bias help in causing the tube to work according to the definitions. Again, it can be seen from the diagrams that the input voltages are progressively greater going from class A to class C via class B. But here again these things do not make the amplifiers what they are.

For example, if a tube is biased to cut-off the input voltage can have any value, but the amplifier will always be operating in class B. To take a further example, consider the case of a valve biased much closer to cut-off than to the zero bias line. The fact that it is biased in this way does **not** determine to what class it belongs, since with only a small input voltage it would be operating class A, with a larger input voltage it would be operating class AB, and with a larger voltage still, class B.

The point to be made here is that in defining the class of an amplifier the actual operating conditions individually have no bearing on the matter. It is only when all the operating conditions are taken into account and the end result is noted that the

class of amplifier can be stated.

It may seem to some that such insistence upon proper definition is academic, and impractical, but such is not the case at all. Terms such as those under discussion are a convenient means of shorthand among technical people versed in a particular subject, but if the exact meanings of the terms are not stated, or if there are no exact meanings, then the shorthand becomes confusing, which is exactly what has happened to the classification of amplifiers.

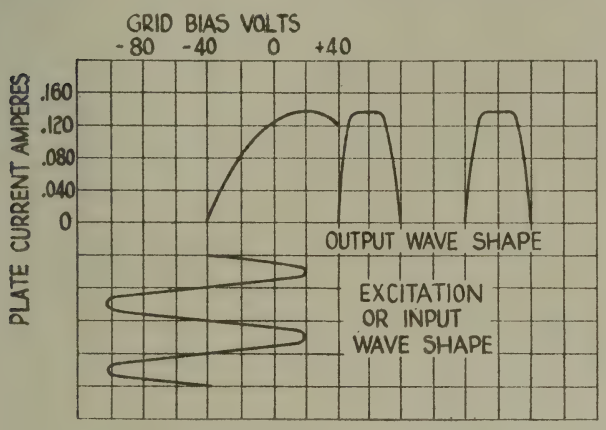

Fig. 2. Class B_2 Amplifier.

THE QUESTION OF SUBSCRIPTS

A little of the trouble caused by the subscript numerals to indicate the presence (or otherwise) of grid current has already been indicated. In our opinion, these numerals should be used with every literal classification, at all times.

As was pointed out earlier, there seems to be a tacit assumption in the term "class A" that there shall be no grid current at any part of the input cycle. Similarly, "class B" and "class C" have grown to imply that grid current is present. These tacit assumptions, inherent in the omission of the numerals from the classification, are tantamount to denying the possibility of such operation as A_2, B_1, and C_1. True, these types of operation may be unusual—even exceptional—but they are possible, and even common in some types of equipment.

To give an example, a valve acting as a pulse amplifier, grid modulated in such a way as to produce amplitude-modulated pulses, is operated in class C_1. That is to say, plate current flows only during the positive pulse excursions, and yet at no stage is grid current allowed to flow, because if it did the modulation would no longer be linear.

Since examples such as this can readily be found in current practice, there seems to be no good reason for omitting the numerals, and every reason for including them at all times. Not only do the subscripts complete the picture, but if used all the time, they eliminate much possible misunderstanding.

ACQUISITION OF MEANINGS

It is unfortunate, but in some ways inevitable, that technical terms, like other words, should acquire by association, meanings other than those implied in their definition. For example, it has long been thought that class A amplifiers are capable of higher fidelity than those of any other class. It has recently been shown that this is not necessarily so, but the statement may be said to have as much truth as a good many generalisations. Because of it there is a pronounced tendency to regard a class A amplifier as one which is biased in the middle of the straightest portion of the valve's mutual characteristic, and in which the input voltage is limited to this straightest portion. If it is realised that such operation is the method whereby a class A amplifier is caused to operate with least distortion, well and good, but it

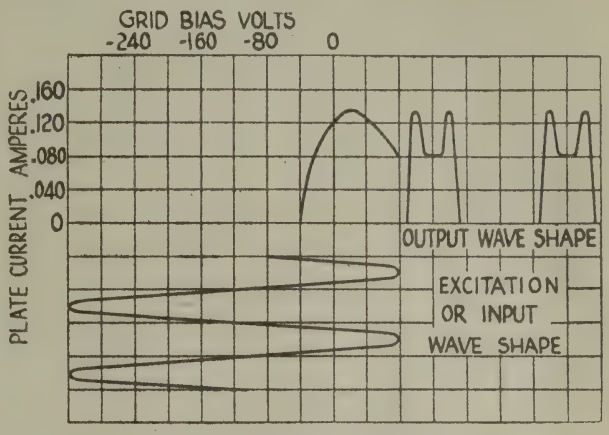

Fig. 3. Class C_2 Amplifier.

should be noted that the term class A does not in itself imply this type of operation. As long as the valve is operating with plate current at all times, its operation is class A irrespective of how much distortion it produces.

There is a very informative example of this in a number of British radar receivers that were produced during the early years of the last war.

The problem was one of providing as much output voltage as possible from a pair of small pentodes connected in push-pull so as to give balanced deflection for the Y-plate of the display C.R.T. It was very ingeniously solved by having regard to the input waveform, which consisted of very narrow pulses. Because of this the tube whose grid accepted the pulses in the positive-going phase was biased almost to cut-off, while the other tube was biased as little negatively as its plate dissipation would allow, since the signals at its grid were negative-going pulses, identical in shape but reversed in phase as compared with the input to the first tube.

Further than this, the amplitude of the input to the first tube was arranged to be greater than that applied to the second one. This is because the former was working over a region of lower average mutual conductance than the operating region of the latter. The net result was equal out of phase signal voltages at the plates of the two tubes, in spite of their differing biases and input voltages. The whole arrangement as described is a special form of class A push-pull amplifier, because in each tube the bias and input waveforms are such that plate current flows at all times. Yet if such a stage were provided with sine-wave input of only moderate amplitude, the distortion would be severe, because one tube would be operating in class AB_1 and the other in class A_2.

Thus, through unusual conditions of input wave-

form, the real classification of the amplifier is quite different from what it would be under other conditions of input voltage. Unless the fundamental definitions given at the beginning of this article were used, such an amplifier would be incapable of classification, and the classifying system would break down.

Other examples can readily be found of the accretion of non-fundamental meanings to the classifications. One has already been mentioned, namely, the assumption of grid current in class B and class C amplifiers, but there are many others and all of them tend to obscure the real meaning of the terms.

CLASS A AND CLASS AB

A very bad example of the sort of confusion which has arisen with the system of classifying amplifiers is that which surrounds the class AB amplifier. Too many textbooks define this as being intermediate between class A and Class B, and leave it at that. The result is that the question, "What constitutes the dividing-line between class A and class AB operation?" brings forth blank looks and a suspicion that it is a "catch" question. If our definitions are taken, there is no difficulty at all. An amplifier ceases to be class A and become class AB the moment the plate current drops to zero at the negative peak of the input signal. And yet one very well known textbook rather leads the reader to believe that the question is solely one of bias in relation to the mutual characteristic of the valve, making no explicit statement whatever.

OTHER TRANSITIONS

It should in fairness be pointed out that though there **is** a sufficiently clear-cut dividing-line between class A and class AB, such is not the case between class AB and class B; or between class B and class C. This is because of the inevitable latitude contained in the definitions of class AB, B, and C amplifiers. It would be unnecessarily restrictive if, by definition, a class B amplifier passed plate current for **exactly** a half cycle of the input voltage, because in practice many class B amplifiers (particularly those using zero-bias tubes) pass a small but definite plate current with no signal input. Such an amplifier still fulfils the condition laid down by the definition. For this reason there can be no hard-and-fast dividing-line between class AB and class B working, nor can there be any between class B and class C.

THE CLASS "BC" AMPLIFIER

There has arisen in the literature comparatively recently a new class of amplifier which has been called class BC. This term is used to refer to a particular type of grid-modulated amplifier, but without going into the manner of operation of this ampli-

(Continued on page 56.)

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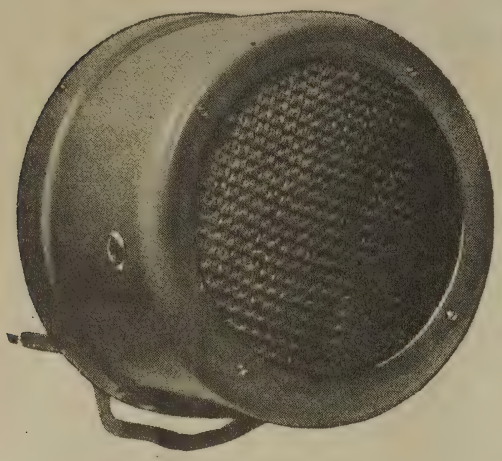

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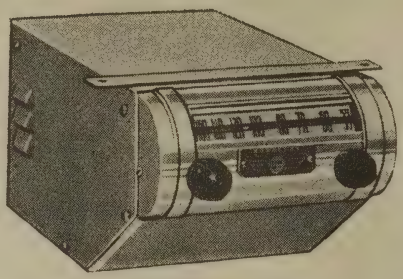

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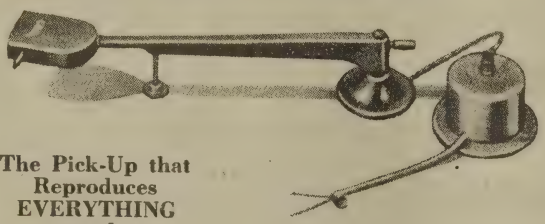

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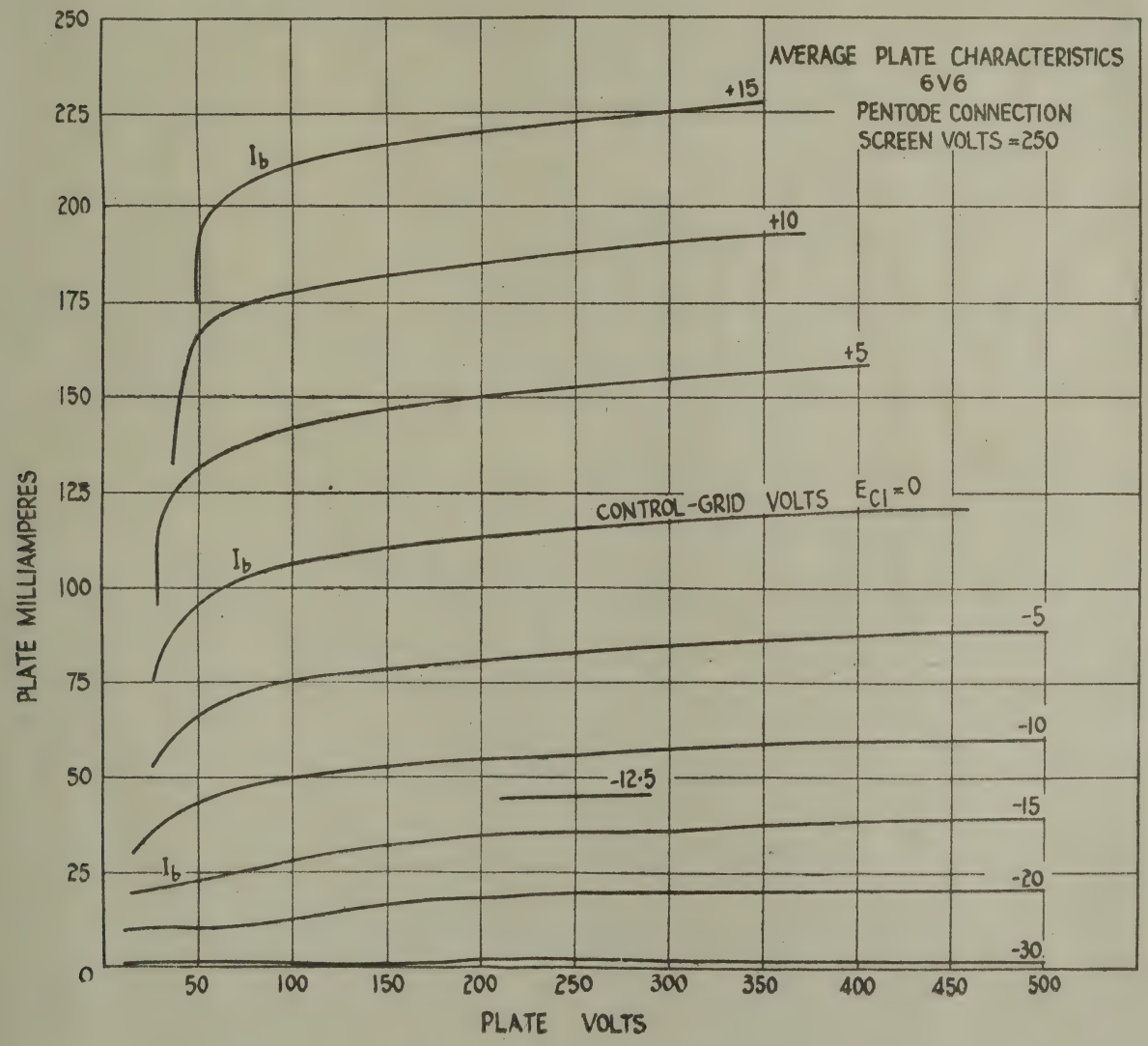
TUBE DATA : Plate Characteristics of Type 6v6, 6v6-G and 6v6-GT

Below are given the characteristics of the above tubes for a screen voltage of 250, and for grid voltages between — 30 and + 15. The positive portion of the grid characteristic (to be printed separately in another issue) in conjunction with the curves presented here enable amplifier stages to be designed which normally take grid current, such as class AB_2, B_2 and C_2 amplifiers.

The three types mentioned are identical electrically except for inter-electrode capacities, which are as follows:—

Capacity	6V6	6V6-G	6V6-GT
Grid-plate	0.3	0.7	4.7 mmfd.
Input	10.0	9.5	9.5 mmfd.
Output	11.0	7.5	7.5 mmfd.

Normal bias for single valve class A_1 operation is — 12.5 volts, so that a small portion of this curve has been drawn to allow the operating point to be accurately located under these conditions.



Tracking Error in Gramophone Pick-ups

In this article the term "tracking error" is explained, and some indication is given of its importance and how it may be kept to a minimum.

Within the last year or two a great deal of work has been done on the subject of gramophone pick-ups and how improvement can be made in their characteristics. Principles new to pick-up construction have been tried in the laboratory with notable success, and some of the results of such work have even arrived at the stage of being put on the retail market.

Some of these new pick-up types such as the moving-coil and electrostatic varieties are quite suitable for home manufacture, and quite a number of articles describing their detailed construction have appeared in overseas periodicals. This has stimulated quite an amount of experimenting by amateurs and others interested in record reproduction. Practically all such articles, however, deal only with the construction of the pick-up heads themselves, leaving to the individual important matters such as the design of the pick-up arm.

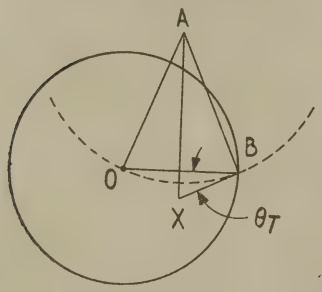


Fig. 1.

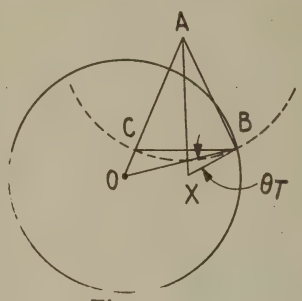


Fig. 2.

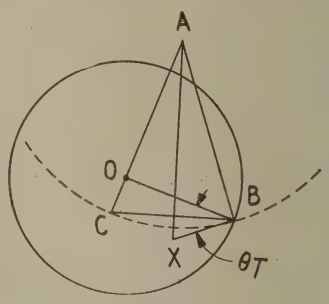


Fig. 3.

IMPORTANCE OF ARM DESIGN

In some respects, the design of a suitable arm is of just as great importance as that of the head, for however good may be the latter's characteristics, the results obtained from it can be rendered very poor by the use of a badly designed arm. It is not intended here to go into all the ramifications of arm design, but this article deals with one of the most important factors, namely, tracking error. This is very important to the proper performance of the pick-up, and luckily, can be treated quite separately from other equally important factors such as the absence of resonance and methods of counter-balancing.

WHAT IS TRACKING ERROR?

It is well known that when disc recordings are made, the cutting head, which makes the groove and simultaneously modulates it with speech or music, moves radially from the outside exactly towards the centre of the record. By this means, the lateral vibration of the recording stylus is always at right-angles to the direction of the groove. Thus, when a record is being reproduced, the playback needle should ideally be moved towards the centre in the same way as the recording stylus—i.e., radially—in order to ensure that the movement of the playing needle exactly follows that of the cutting stylus.

This ideal state of affairs could be achieved only by means of an expensive mechanical arrangement similar to that used to move the cutting head in the recording lathe, and is therefore impossible to realize economically. Instead, the pick-up is mounted on an arm of fixed length, which pivots about a point outside the area covered by the turn-table, with the result that the reproducing needle, instead of moving along a radial track, follows the arc of a circle whose radius is the distance between the pivot point, and the needle point. This is illustrated in Figs. 1, 2, and 3, in which O is the centre of the record, and A is the point on which the pick-up arm is pivoted. The full circle represents the outside perimeter of the record, while the dotted arc is the path travelled by the pick-up needle. In all three diagrams, B is the point at which the needle touches the outside groove of the record. Even a casual inspection of these diagrams is enough to show that with a mechanical arrangement of this kind it is not possible for the ideal condition for the movement of the pick-up needle to be realised over the whole travel from outside to inside on the record.

Thus the meaning of the term "tracking error" can be seen from a consideration of Fig. 1. Here BX has been drawn at right-angles to AB, the pick-up arm. Now since the head is fixed to the end of the arm in such a way that the side-to-side movement of the needle is always at right-angles to the line of the arm, BX represents the direction of movement of the needle point, caused by the lateral waves in the record groove which represent the recorded sound. Also, since AB is a radius of the dotted circle, XB must be a tangent to this circle. But OB is a radius of the record, and for the needle always to execute radial vibrations with respect to the record OB is the path on which ideally the pick-up head should move.

Thus we have OB as the line in which the needle **should** vibrate when it is at B on the record, and XB as the line in which it actually does vibrate. The angle OBX is therefore called the angular tracking error, or simply the tracking error for short. It is clear that for the best results, this error should always be as small as possible.

As the pick-up follows the record groove and moves closer to the centre of the record, the size of the tracking error changes. If a new point B is imagined, somewhere along the dotted arc OB (i.e., nearer to the centre of the disc), it can be seen from Fig. 1 that the angle OBX will be smaller than it is at the outside of the record, because the closer we go to the centre of the disc, the more nearly do OB and

BX coincide. Ultimately at the centre of the record these two lines do coincide, and the tracking error is zero. However, this fact is of only academic interest, because the recording is seldom taken closer than two inches from the centre of the disc. Thus, for the state of affairs illustrated by Fig. 1, there is always some tracking error, and this is greatest at the outside of the record. It will have been noted by now that Fig. 1 is drawn for the special case where the arc of swing of the needle passes through the centre of the record.

REDUCING TRACKING ERROR

Having seen what tracking error is, the question arises, "How can it be reduced to a minimum?" The most obvious ways are either to use a very long pick-up arm, or else to devise a mechanism which rotates the pick-up head on the end of the arm as the latter swings toward the centre of the record. The latter scheme has actually been used a number of years ago by an English manufacturer, who turned out an arm whose head swivelled by means of a system of levers, and so kept the line of vibration of the needle radial with respect to the record. However, such systems are costly and difficult to manufacture satisfactorily, and are almost impossible to make both effective and pleasing in appearance.

Again, increasing the length of the arm to any useful extent is ruled out by reason of the large space required for mounting.

It is possible, however, to reduce the tracking error on 12-inch discs to a maximum of about 3° (which can be regarded as negligible) by the now well-known expedient of off-setting the pick-up head on the arm. By off-setting is meant the practice of mounting the head at a fixed angle with respect to the line of the arm, so that the lateral vibration of the needle is no longer at right-angles to the line of the arm. For a 12-inch record and a maximum tracking error of 3°, the arm can be as short as 8 inches with a properly designed arm. How this can be brought about will be seen later.

LENGTHENING THE ARM

Using the simple system of Fig. 1 in which the arc of the needle passes through the centre of the record, any desired improvement can be obtained by simply using a longer arm, as described above. The performance of such a system can be estimated from Fig. 4, which gives two curves of tracking error against length of arm. The upper curve gives the error when the needle is at the outside edge of a 12-inch record, and the lower one gives the error at a radius of 1½ inches, which can be taken as a representative figure for the end of the record. Two things are abundantly clear from these curves: First, that the error at the outside of a 12-inch record is very great with short arms, and requires a very long one to reduce it to a reasonable figure; and secondly, that a reasonably short arm reduces the difference between the errors at the outside and inside of the record at about the same rate as the maximum error is reduced. This question of the difference between maximum and minimum errors with a given arm arrangement is an important one with respect to finding the best angle at which to offset the head, in cases where this can be done, and in finding the remaining maximum error when the offset is taken into account. From Fig. 4 it can be seen that the arm would have to be impossibly long in order that the tracking error may be reduced to 3° at the outside of the disc.

OTHER METHODS

The discussion so far has centred on the case illustrated in Fig. 1, but the question arises, "Is there any advantage to be gained by mounting the pick-up in such a way that the needle swings not through the centre of the record, but on one side of it?"

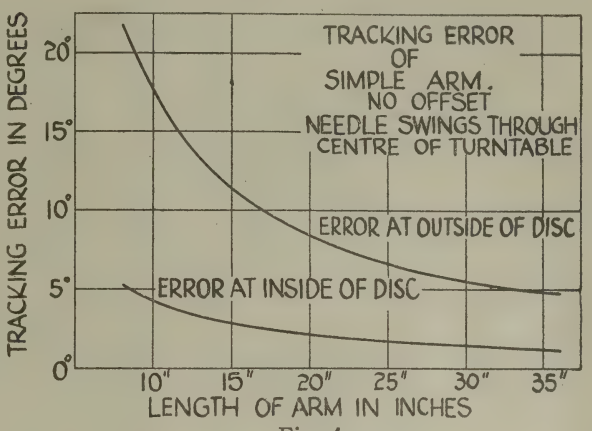


Fig. 4.

This question brings up two more cases which are illustrated in Figs. 2 and 3. In the former, the arc of the needle passes between the centre of the record and the pivot point of the pick-up. In the latter, the needle arc passes outside the centre of the record.

This particular case is of interest because it enables the tracking error to be made zero at one particular point on the record. In this way there is some error at both the inside and outside of the disc, less in quantity than if the simple system of Fig. 1 is employed.

EXAMPLE OF USE OF FIG. 2.

Taking the case of an 8-inch arm, which is representative of the lengths used for pick-ups designed to play up to 12-inch records, and assuming that the point of zero tracking error is at 4 in. radius on the record (approximately after half the record has been played), the following figures are obtained:—

Distance between pivot-point of arm and centre of record (OA on Fig. 2)	8.9 in.
Tracking error at outside of disc	9.1°
Tracking error at inside of disc	7.4°

Comparing these figures with those for the arrangement of Fig. 1, as shown in the graph Fig. 4, it can be seen that this method effects a considerable improvement.

CASE ILLUSTRATED IN FIG. 3

In Fig. 3 we have the third case which completes the general treatment. Here the pick-up needle swings in an arc **outside** the centre of the record. It can be shown that here no combination of dimensions can be found in which the tracking error is zero at some part of the pick-up's travel, so that at first sight it would not appear to confer any advantage at all. However, a disadvantage suffered by Fig. 2 is that here it is impossible to use any reasonable degree of offset on the head in order to improve the tracking. The reason for this is that with the

arrangement of Fig. 2, the **sign** of the tracking error changes as the pick-up passes through the point of zero error. That is to say, the line of lateral vibration of the needle, BX, changes over from the side shown in Fig. 2 to the opposite side of the radius OB, after the point of zero error has been reached.

Fig. 3, however, does not suffer in this respect, and its particular advantage can be seen from Fig. 5. It will be noted that in this case the error obtained

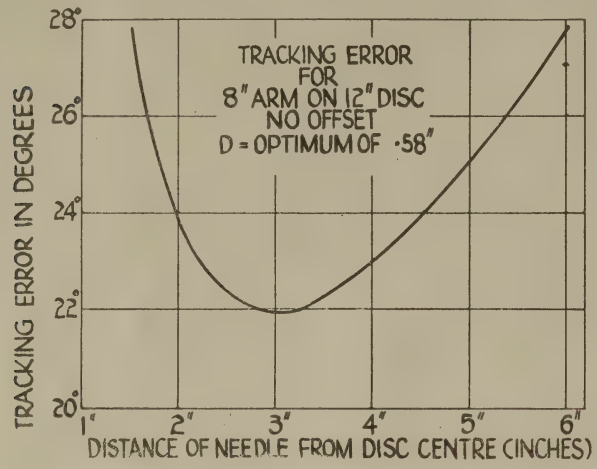


Fig. 5.

with a short (8-inch) arm is very large—much larger than is the case with Fig. 1—but that **the variation in error between the inside and outside of the disc is very small.** This is the most important feature of Fig. 3, and shows that offsetting can be used to great advantage.

OFFSETTING THE PICK-UP HEAD

So far we have been considering the three possible methods of mounting the pick-up arm, and have mentioned the subject of offsetting only in passing. The point arises as to how can offsetting the head reduce the tracking error, and can be briefly explained with the aid of Figs. 1 and 4.

In the case of an 8-inch arm with the system of Fig. 1, Fig. 4 shows that the error at the outside of a 12-inch disc is 22° and at the inside of 10.8°. The average error is therefore

$$\frac{22 + 10.8}{2} = 16.4°$$

Now, suppose that the pick-up head in Fig. 1 is rotated in a clockwise direction through 16.4°, so that there is now an angle of this value between the line of the arm and a line through the needle at right-angles to its direction of lateral vibration. The tracking error at the outside of the record is now

$$22° - 16.4° = 5.6°$$

and at the inside is

$$10.8° - 16.4° = -5.6°.$$

Thus, by offsetting the head by an amount equal to the average error **without** offsetting,, the maximum error has been reduced from 22° to 5.6°—a very worth-while improvement. It will be noted that this result is better than that obtained with the same length of arm and the system of Fig. 2, where the error is arranged to be zero in the centre of the record.

FIG. 3 WITH OFFSET HEAD

From Fig. 5 it is clear that the system of Fig. 3 without offset is quite useless in attempting to reduce the error to a low absolute value. Taking the working surface of the record as between 6 in. radius and 1½ in. radius (which is a little on the generous side), the error varies from 28° to 22°. The important point about this curve is that it reaches a

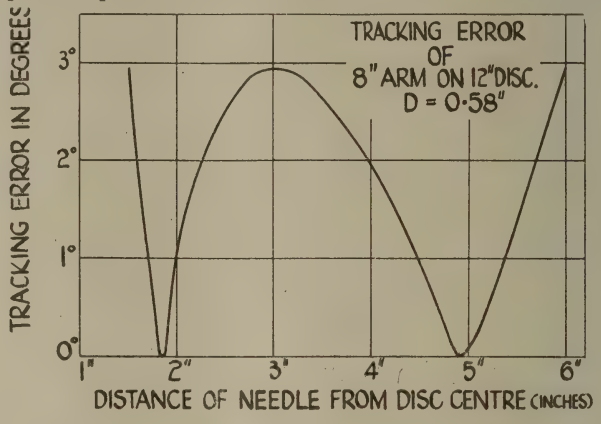


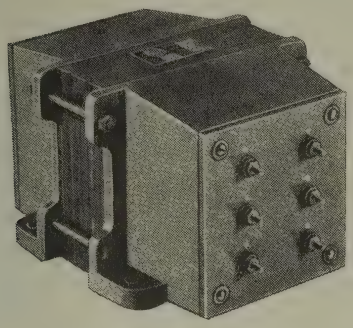
Fig. 6.

minimum and then increases again, arriving at the same value at 1½ in. radius as it had at 6 in. radius. Now, the average error is approximately 25°, so that if this degree of offset is used, the maximum tracking error is only 3°, which is the best result of any presented so far.

The dimension D, referred to on Figs. 5 and 6, is the distance OC on Fig. 3, by which the needle overhangs the centre of the turntable. It can be shown (see appendix) that for a given record size, with both maximum and minimum radii specified, and for a given arm length, there is an optimum value of D which will ensure that the untracked errors at the inside and outside of the disc are equal. This value of D also ensures the minimum possible difference between the maximum and minimum untracked errors, and therefore the best performance after the head has been offset. In the appendix at the end of this article will be found formulae which enable the tracking error to be calculated under any of the conditions met with in Figs. 1, 2, or 3. In addition, since Fig. 3, with offsetting, gives the best possible result for a given arm length, the full derivation is given for the formulae which refer to this case.

EFFECTS OF TRACKING ERROR

The presence of bad tracking error in a gramophone pick-up is harmful in a number of ways to both reproduction and record life. First, and most important, quite severe distortion can be introduced. This arises from the fact that, if there is any tracking error, the needle point has a component of motion in the direction of movement of the record, whereas, with no tracking error, the needle can vibrate only at right-angles to this direction. This causes the record to exert a different force on the needle on alternate half-cycles of the vibration, so that the amplitude of the needle vibration becomes less on the half-cycle on which the needle attempts to travel in the opposite direction to the record



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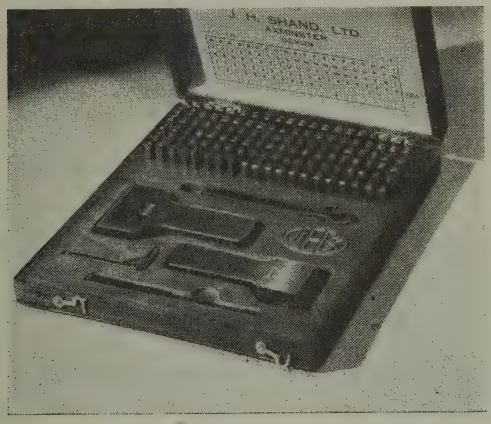

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motion. This inequality is second harmonic distortion. At the same time, the inequality of forces on the needle-point during alternate half-cycles causes a heavily recorded passage to wear much more than it would if there were no tracking error. In extreme cases, it may cause the needle to jump a groove, by imparting a velocity to the head as a whole rather than just to the needle. Alternatively a heavier head is needed to cause the needle to stay in the most heavily recorded grooves, with consequent unnecessarily heavy wear on the more lightly recorded portions. Additional wear on the parts of the record where tracking error is small is caused by the unequal wear on the needle which occurs in the badly tracking portions. Thus, since the effects of record wear are detected both as distortion and increased surface noise, a badly tracked pick-up can greatly reduce the useful life of a record.

It is not intended here to enlarge further upon the deleterious effects of bad tracking, but a good deal has been written about it in the technical literature of record production, and enough has been said here to indicate that the subject is of considerable importance.

Thus, anyone who buys a pick-up, whether a very costly one intended for broadcast studio work or the cheapest type of home pick-up, should always follow to the letter the maker's instructions on the subject of mounting it. However well or badly the arm may be designed, the manufacturer can be relied on to recommend the mounting position which will give the best tracking to his pick-up.

Similarly, with the help of the simple formulae given below, anyone who is designing an arm and head mounting can achieve the best possible results in the space available.

RULES FOR DESIGNING AN ARM

The design of a pick-up arm can be reduced to a few very simple steps, as follows:—

(1) Since, with all the methods of mounting, the longest arm gives the least tracking error, the arm is made as long as space will allow.

(2) When the arm length has been decided upon, the system to be used should be chosen, bearing in mind that Fig. 3 gives the best results.

(3) Bearing in mind the largest record that has to be played equation 8 (appendix) is used to find the optimum length D. (= OC on Fig. 3.)

(4) The appropriate values are inserted in equation, and the maximum error with no offset is found.

(5) Values are inserted in equation to find the minimum error with no offset.

(6) The average of the maximum and minimum

(5) Values are inserted in equations 9 and 7 to find the minimum error with no offset.

(7) A drawing of the complete arm is made, bearing in mind that the pick-up needle must be the same distance from the arm pivot after the head has been offset as was assumed for the arm length in the calculations. For example, if AB on Fig. 3 was originally chosen as 8 in., then, when the arm has been designed, B must still be the position of the needle-point.

* * *

APPENDIX

Formulae for finding the tracking error error in any given case

Case A (Fig. 1)

Where the arc of swing of the needle passes through the centre of the record—

Let A be the radius of the pick-up arm.

Let R be the radius of the record at the outside.

Let r be the radius of the record at the inside.

Let θ_{T_o} be the tracking error at the outside.

Let θ_{T_i} be the tracking error at the inside.

Then we have

$$\theta_{T_o} = \sin^{-1}\frac{R}{2A} \quad \ldots\ldots (1)$$

$$\theta_{T_i} = \sin^{-1}\frac{r}{2A} \quad \ldots\ldots (2)$$

$$\text{Optimum head offset} = \frac{\theta_{T_o} + \theta_{T_i}}{2} \quad \ldots\ldots (3)$$

Case B (Fig. 2)

Where the arc of swing of the needle passes between the pick-up pivot and the centre of the record.

Definitions are as for Case A, with the addition that d = OC on Fig. 2.

As before we have

$$\theta_{T_o} = \sin^{-1}\frac{R^2 + A^2 - (A + d)^2}{2AR} \quad \ldots\ldots (4)$$

$$\theta_{T_i} = \sin^{-1}\frac{r^2 + A^2 - (A + d)^2}{2Ar} \quad \ldots\ldots (5)$$

In this case there is a point of zero tracking error. If r_o is the record radius at which this occurs, we have—

$$r_o = \sqrt{(2A + d)d} \quad \ldots\ldots (6)$$

Also, in this case offsetting cannot be employed.

Case C (Fig. 3).

Where the arc of swing of the needle passes beyond the centre of the record.

Referring to Fig. 3, we have for the tracking error at any record radius R_1.

$$\theta_T = OBX = 90° - ABO$$

In the triangle ABO we have that

$$AO = (A - d)$$
$$OB = R$$
$$AB = A$$

Where A, R, and d have the same meanings as before.

From the triangle ABO

$$AO^2 = AB^2 + OB^2 - 2AB.BO \cos ABO.$$

Rearranging and substituting values, we have

$$\cos ABO = \sin\theta_T = \frac{R^2 + A^2 - (A - d)^2}{2AR}$$

$$\therefore \theta_T = \sin^{-1}\frac{R^2 + A^2 - (A - d)^2}{2AR} \quad \ldots\ldots (7)$$

For optimum tracking after offsetting the pick-up head, θ_{T_o} must equal θ_{T_i} or $\theta_{T_o} - \theta_{T_i} = 0$.

$\therefore \sin\theta_{T_o} - \sin\theta_{T_i} = 0.$

(Continued on page 55.)

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DESIGN SHEET No. 5 A Superheterodyne Tracking Chart

In the literature a great many formulae are to be found for designing the oscillator circuit constants to give three-point tracking over a given range of signal frequencies. Most of these formulae are straightforward enough, but entail a great deal of arithmetical work, with consequent liability to error.

The accompanying chart is one that was developed by P. C. Gardiner of the General Electric Co., Schenectady, U.S.A., as a means of simplifying the calculation of the oscillator inductance, parallel capacity and series capacity (padder) necessary to track with a given R.F. circuit, using a specified condenser gang.

SIGNAL CIRCUITS

In the top left-hand corner of the chart are the signal and oscillator circuits to which the chart applies. Taking the signal circuit first, C_t represents the minimum circuit capacity, and includes the minimum capacity of the gang condenser, the self-capacity of the R.F. coil, the trimming capacity in use, and the stray wiring capacities.

The first thing to decide is the tuning range to be covered. When this is known, the gang capacity is decided upon. In the diagram, C_v represents the **capacity variation** of the gang condenser, and **not** its maximum capacity. This enables calculations to be made of the total parallel capacity C_t.

First, suppose that F_1 is the lowest R.F. frequency and F_2 is the highest R.F. frequency in the required range. It may be shown that

$$\frac{C_t}{C_v} = \frac{F_1^2}{F_2^2 - F_1^2} = \frac{F_1^2}{(F_2 + F_1)(F_2 - F_1)} \quad . \quad . \quad . \quad (1).$$

Since C_v is known, and F_1 and F_2 have also been chosen, equation (1) enables the required value of C_t to be worked out. When C_t has been evaluated, the value obtained should be compared with the figure for the minimum capacity of the gang section. Should C_t, as calculated, come to less than the minimum capacity of the gang, the gang is unsuitable and another must be chosen having either a higher maximum capacity, a lower minimum capacity, or both.

If the value of C_t obtained is only a few micro-micro-farads more than the gang's minimum, the gang will still be unsuitable, since the inevitable stray capacities plus the self capacity of the coil will bring the minimum capacity to a higher value than C_t.

The advantage of this method of working out the signal circuit constants is that the stray capacities need not be accurately known. All that needs to be known is that the strays plus the minimum gang capacity add up to less than a given amount—namely, C_t.

It should be noted that in practice, the extra capacity required to make up the difference between C_t and the strays, etc., is provided by the trimmer.

OSCILLATOR CIRCUIT

When the signal circuit capacities have been fixed as above, it is possible to use the chart to arrive at the values of C_1 and C_2, which are the total parallel and the padding capacities respectively of the oscillator circuit.

The only additional information required is the value of the intermediate frequency. Examination of the main chart shows that the padder capacity C_2 is given in terms of the ratio of the I.F. to the highest signal frequency, and the ratio of the highest to the lowest signal frequency. These two ratios must first be worked out, and may then be applied to the chart to give an answer for C_2/C_v or the ratio of padder capacity to the capacity variation of the tuning condenser. Since C_v is already known, this gives the value of C_2 by a simple calculation.

To take an example of the use of the chart to find C_2, suppose that the R.F. signal frequency range is 10 to 15 mc/sec. and that the I.F. is 3 mc/sec. Further, the capacity variation of the gang is 50 mmfd. From this information we have that the R.F. range is 15/10 or 1.5: 1. Further, the ratio of I.F. to highest signal frequency is $3/15 = 0.2$. Now, entering the chart at 0.2 on the horizontal scale we travel vertically until we cut the straight line labelled "R.F. range = 1.5: 1. We then proceed horizontally to cut the vertical scale at a value of 0.7, so that $C_2/C_v = 0.7$. Since $C_v = 50$ mmfd., $C_2 = 35$ mmfd.

The smaller graph is now used to find the value of total parallel capacity C_1. Entering this graph at a value of 1.5 on the horizontal scale and proceeding vertically until the curve is reached, we find that we cut the latter at a value of 0.85. Thus, $C_1/C_v = 0.85$, and $C_1 = 42.5$ mmfd.

The only remaining things are to find the inductances of the R.F. and oscillator circuits.

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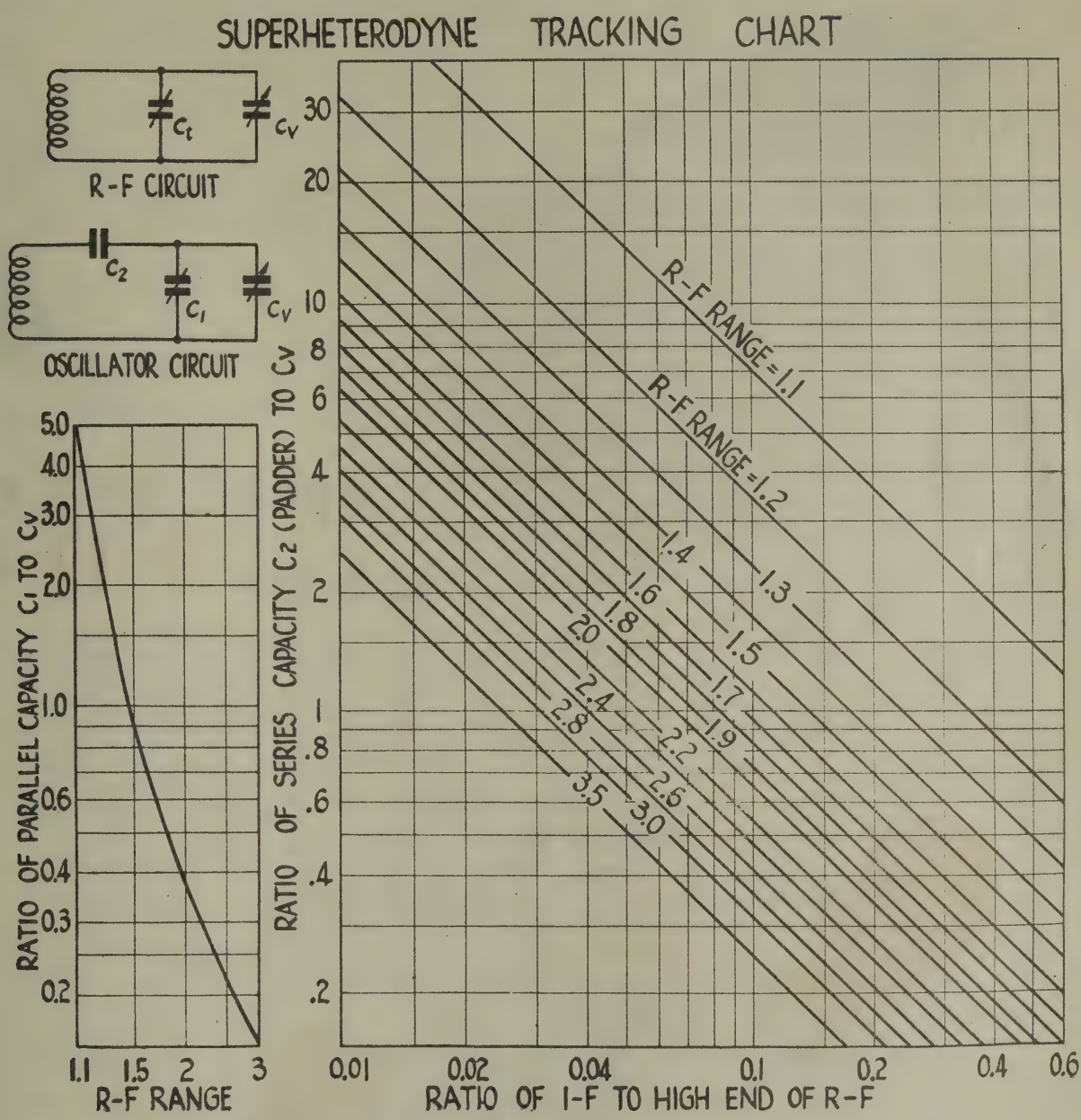

R.F. INDUCTANCE

At the lowest R.F. frequency, F_1, we have a total capacity of $(C_t + C_v)$. Thus the signal circuit inductance is

$$L_s = \frac{25{,}250}{(C_t + C_v)F_1^2} \text{ microhenries} \quad \ldots \quad (2)$$

where F_1 is in mc/sec., and the capacities are in micro-micro-farads.

OSCILLATOR INDUCTANCE

To get the oscillator inductance, the maximum oscillator capacity must be found from the already known values of C_v, C_1 and C_2. The maximum capacity is therefore C_2 in series with C_1 and C_v in parallel. Thus we have

$$C_o = \frac{C_2(C_1 + C_v)}{C_1 + C_2 + C_v} \quad \ldots \quad (3).$$

The oscillator inductance may now be found from the equation

$$L_o = \frac{25{,}250}{C_o(F_1 + \text{I.F.})^2} \quad \ldots \quad (4).$$

(Continued on page 56.)

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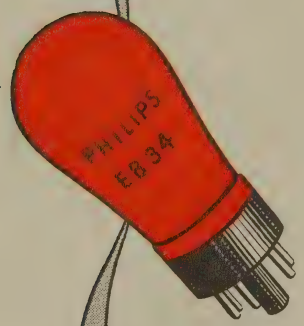

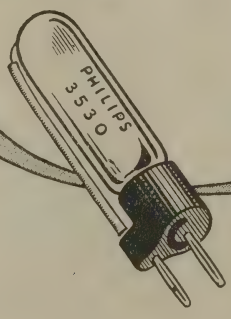

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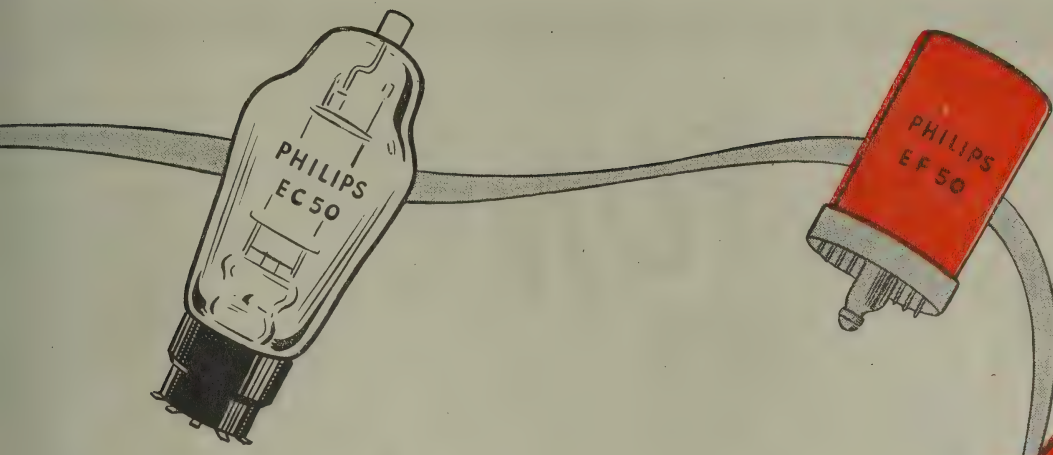

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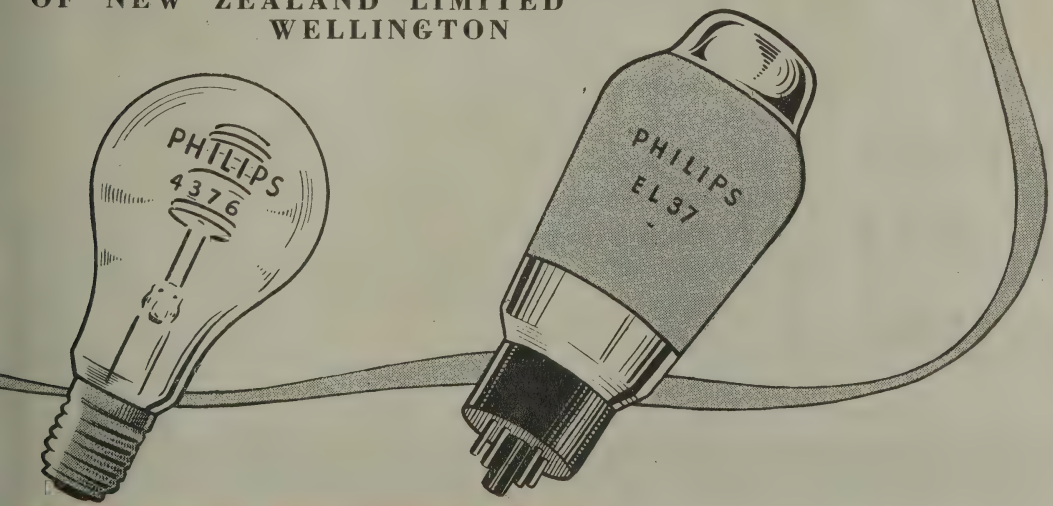

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The Suppression of Electrical Interference

(By the technical staff of Messrs. Belling and Lee, Ltd., Middlesex, England.)

CAUSE OF INTERFERENCE

With the growing number of electrical and electronic appliances and equipment, the question of high-frequency interference with radio communication and broadcast reception is one which calls for urgent attention and positive action. It is not always realized, even by engineers, that, with certain types of electrical equipment in which the normal operating current is suddenly varied or interrupted, pulsating currents arise which have component frequencies within the normal radio frequency channels. With electronic equipment, the interference will usually be in the same channels, either on the fundamental frequency of the equipment or its harmonics.

Interference may be conveyed to the receiver in three different ways. They are:—

(a) Conducted interference. This type is conducted into the receiver through its power supply lead.

(b) Radiated interference. Here the interference is produced by the field of the interfering appliance and enters the receiver via its aerial system.

(c) Re-radiated interference. This is really a combination of (a) and (b), as it is due to the field of the wires, cables, or other conductors which may be connected directly or indirectly with the offending appliance.

High-frequency interference currents in the power supply leads of an appliance usually have two components, known as the symmetrical and the asymmetrical. The former has its e.m.f. between the conductors, whilst the latter has its e.m.f. between the frame of the appliance and the conductors. As the appliance is usually earthed or has a fairly large capacity to earth, the asymetrical component is propagated simultaneously along the conductors and returns to the appliance via the earth. Suppression of such interference is highly desirable, and this may be secured to an adequate extent by the employment of devices involving the use, either separately or in combination, of capacitors, resistors, and inductors. In special instances, it may be necessary to employ screening arrangements.

PRINCIPLES OF SUPPRESSION

Freedom from interference to an adequate degree may be obtained by employing suitable suppression devices whereby the H.F. currents are either restricted or diverted in such a manner as to prevent both radiated and mains-conducted interference. The devices required for this purpose are mentioned above, in which the capacitors provide a by-pass for the interfering currents, the inductors effect a reduction in the magnitude of such currents, whilst resistors may be employed in conjunction with capacitors for quenching sparking and arcing. Appliances producing a field of high radiation may have to be completely enclosed by a screened compartment.

Where capacitor suppressors are used alone on solidly earthed appliances, safety precautions do not restrict to any great extent the capacitance values. Generally speaking, such appliances can usually be suppressed by the application of capacitors alone, the method of connection being in such a manner as to reduce both the symmetrical and asymmetrical components of the interference. Where solidly earthed appliances have such a low impedance at radio frequencies that capacitor suppressors (of any value) cannot produce the required degree of suppression, a combination of capacitors and inductors has to be employed.

Appliances which are not solidly earthed prohibit the use of large capacitance capacitors from a safety point of view. Two examples of the limit in values are as follows:—

Electrical supply.	Max. permissible capacitance of capacitors connected to exposed metal work of appliances not solidly earthed		
	Line to neutral	Neutral to metal work	Line to metal work
A.C. exceeding 110v. but not 250v.	10 mfd.	0.005 mfd.	0.005 mfd.
D.C. exceeding 110v. but not 250v.	10 mfd.	0.1 mfd.	0.1 mfd.

When it is found necessary to suppress interference arising from a solidly earthed appliance which has a low impedance at radio frequencies, one generally finds in practice that capacitors should be connected to the appliance side of the inductors, but occasionally some advantage can be gained by connecting them on the mains supply side of the inductors.

Connecting leads of capacitors should be kept to the absolute minimum length and they should be of the requisite type, i.e., voltage rating, appropriate to the position in which they are to be connected and the supply voltage concerned.

Certain types of electrical and electronic appliances produce heavy interference at considerable distances, owing to intense direct radiation. In these cases, suppression can only be achieved by the use of a screened enclosure. This enclosure must be complete, particular attention being paid to doors making multi-point electrical contact when closed. Also, any kind of supply service to the enclosure must be adequately filtered to prevent propagation from the compartment. The screening material used in the construction of such enclosures need not be solid sheet metal, when considering normal radio communication frequencies; such materials as perforated sheet zinc or fine-gauge wire mesh give quite satisfactory resultts.

SUPPRESSION AT RECEIVER END

The foregoing deals chiefly with the suppression of electrical interference at its source. Such precautions are not always within the control of the person suffering the interference and therefore the necessary action has to be taken at the receiver end.

Referring to an earlier paragraph, it was stated that interference may be conveyed to the receiver in any one, or combination, of three ways, namely, mains conducted, radiated, or re-radiated. Tests have to be made to discover which form of interference is causing the trouble, and, where conducted inter-

ference is found, a set lead suppressor should be fitted at the power supply point. A mains entry suppressor might be inserted at the entry of the mains supply to the premises, as an alternative to using set lead suppressors at all power points. Such a unit would obviously have to carry a large part, or possibly the whole, of the load of the building. The

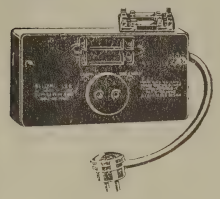


Fig. 1. Showing a typical set-lead interference suppressor.

permissible inductance of the inductors is therefore limited owing to voltage drop. See Fig. 1.

If radiated or re-radiated interference is present, it can usually be reduced or eliminated by the use of an anti-interference aerial system. Such an aerial can consist of either a vertical rod or horizontal wire plus aerial and receiver impedance matching transformers, which are coupled by a screened balanced twin feeder line. It is essential that the collector portion of a system, i.e., the rod of horizontal wire, be erected outside the interference field, otherwise the object will be defeated. The screened feeder line must, of course, run through the interference field, but this does not convey interference to the

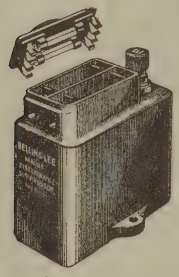


Fig. 3. Capacitor suppressor for a motor or generator that is solidly earthed.

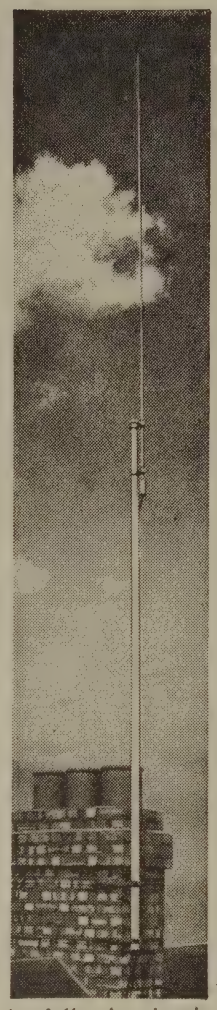
Fig. 2 (opposite column). Typical vertical aerial mounted on a chimney mast so as to be outside the interference field of the house.

receiver. The transformers, if carefully wound with the appropriate characteristics, will give good response to all the normal broadcast transmissions within the 10-2000-metre band. See Fig. 2.

TYPICAL SOURCES OF INTERFERENCE AND SUPPRESSION DEVICES

Commercially produced filters are now available to give the requisite attenuation in the frequency range 30 m/cs. to 150 k/cs., with inductors capable of carrying loads between 1 and 300 amps. In the case of commutator-type motors, it is often possible to render such suppressors more effective on the higher frequencies by connecting capacitances of the order of 0.01 mfd. to 0.001 mfd. directly between the brush holders and frame.

In the first category of sources of interference we can place fractional h.p. motors, or appliances incorporating such motors, but excluding thermostats. Typical examples are fans, drink mixers, pumps, ice-cream machines, vacuum cleaners, electric toys, etc. Most types usually can be suppressed by capacitor suppressors alone, except A.C. or universal motors not solidly earthed, when filters are required. Sewing machines may need special filters in some cases. It should be noted that A.C. induction motors are inherently non-interfering if in order.



The next category covers large motors and generators. Generally these are solidly earthed appliances, and capacitor suppressors will often produce the required degree of suppression. See Fig. 3.

Three-phase A.C. machines will require capacitors between each phase and frame or neutral. In cases where capacitor suppressors prove ineffective, filters will invariably provide a satisfactory answer.

Thermostats can be considered in a category of their own. Well-known examples of appliances incorporating thermostats are electric irons, electric radiators, electric cookers, electric blankets, etc. Capacitors connected across the thermostat may give the required degree of suppression, but usually some form of filter is found necessary. Appliances such as those just mentioned, but without thermostats, do not normally cause interference if in order.

Under the heading of miscellaneous appliances, such items as oil-burners, adding machines, luminous discharge tubes, electric lifts, electro-medical appliances, and industrial H.F. equipments may be considered, to give some idea of the field to be covered. Almost all such appliances require special treatment and have to be treated as individual cases. However, the following is given as a general guide. It may be taken that oil-burners require resistors fitted in the electrode leads, in the same manner as sparking-plug suppressors in a motor car and electrodes may have to be screened. A filter will undoubtedly be required in the power supply, especially if this is D.C. and the A.C. needed to operate the plant is obtained from a rotary converter.

Adding machines require a special combination of a mains filter and inductors fitted immediately adjacent to the governor contacts. Luminous discharge tubes, cold cathode type, require all H.T. leads and metal work to be bonded and earthed, with a 50-henry inductor at the centre of the tubes. The hot-cathode type require a capacitor across the lamp, the capacitance of which should not be prejudicial to the satisfactory operation of the lamp. Suppression of electrically-operated lifts can be quite complex, but usually the interference can be reduced to a low level by fitting capacitor suppressors or filters to the motors, filtering the control circuit supply, and fitting conductors in the trailing cable circuits at the half-way box in the lift shaft.

(Continued on page 56.)

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A Practical Beginners' Course

PART 16

Last month we saw how a triode can be connected to give more sensitivity than a crystal or diode detector. The circuit used was that of Fig. 27 in which a small "B" battery of 10 volts or more is used solely for supplying the plate circuit of the valve. This type of detector is known as a **grid-leak detector** on account of the resistor R_1 which is called the grid-leak because it enables the D.C. grid circuit to be completed, and prevents a charge of electricity from building up on the grid. This type of detector is quite sensitive, and will give a stronger signal in the headphones than either the diode or crystal circuits we have used in previous experiments, but it is still not sensitive enough to enable us to receive anything but local stations, unless we have an exceptionally high, long aerial, such as is seldom seen these days.

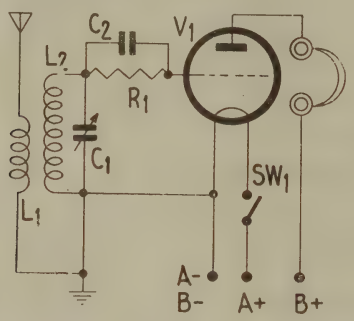


Fig. 27

HOW CAN DISTANT STATIONS BE RECEIVED?

If the circuit of Fig. 27 is still not sensitive enough to receive distant stations, how is it, then, that single valve sets can be used to receive signals literally from the other side of the world? Such sets must have a great deal more sensitivity than any we have built so far. The answer is in the principle called **regeneration.** This principle enables extremely high sensitivity to be obtained, so high in fact that signals of only a few millionths of a volt can be easily heard and read on a sensitive set of 'phones. But before we go on to say exactly what regeneration is and does, we will now digress a little to see what other methods are used to enable us to receive very weak and distant signals.

One might think at first sight that the principle of regeneration would be the answer to the whole problem, but this is by no means a fact, as must be obvious when we remember that most sets in use to-day use five valves at least, and that the better ones have up to fifteen or sixteen valves. In fact regeneration is now frowned upon by commercial designers to such an extent that hardly a set made by a manufacturer employs this principle to-day. This does not mean that for amateur and experimental purposes the regenerative set is of no use. It is of immense value even to-day, and can often produce as good results as much more complicated circuits. The reason for its fall from popularity in the commercial world is mainly that it is tricky to adjust, and cannot readily give some of the other advantages that more complicated circuits confer. However, it is still the principle by which the greatest sensitivity may be obtained with the smallest number of valves—which accounts for its popularity for some purposes even now.

OTHER METHODS OF OBTAINING SENSITIVITY

What, then, are the methods by which a set may be given more sensitivity than a simple detector has, and yet do not involve the use of regeneration?

All the various methods really come to the same thing when they are analysed — the provision of amplification, either before or after the detector, or both at once. We will deal with some practical amplifier circuits when we have built a few regenerative sets using only one valve, but it is a good thing for you to have some idea at this stage of how more complex sets are built up.

In order to provide amplification or enlargement of the currents picked up by the aerial, we must use valves. Now these can be used after the aerial, but before the detector, to amplify the R.F. currents from the aerial before the detector is asked to turn them into audio frequency currents. Alternatively, the aerial can work straight into the detector circuit, as it has done in all our sets so far, and valves can be used to amplify the audio frequency currents provided by the detector, before these are fed to the headphones.

The first kind of amplifier is called an **R.F. amplifier** because of the R.F. currents it handles, while the latter is called an **A.F.** or **audio frequency amplifier**, for obvious reasons.

At first sight it might seem that if, say, one extra valve was to be used, it would not matter whether it were connected as an R.F. or audio amplifier. For instance, it is often possible to get more amplification from a particular valve if it is used as an audio amplifier than can be got from the same valve in an R.F. amplifier circuit. In this case, it would seem better to use the audio circuit, but this is not necessarily so. The reason is that detectors do not function as well on very weak signals as they do on moderately strong ones. Thus, if we want our set to pick up more stations, it will be better to have an R.F. amplifier, so that the very weak R.F. signals arrive at the detector as comparatively strong ones.

But if we are interested only in obtaining greater volume in the 'phones from stations that can already be heard without an amplifier valve, the best thing to use is an audio amplifier.

Again, if one valve besides the detector does not give enough amplification, two or more may be used. For example, a third valve could be used as an additional R.F. amplifier. In this case the line-up would be as follows:—The aerial would feed the first R.F. amplifier valve. The output from this valve would feed the grid of the second R.F. amplifier, which in turn would feed the detector.

In a similar way we could have a three-valve set in which there were no R.F. amplifiers, but the detector and two audio amplifiers, the first feeding into the grid of the second, and this in turn feeding the headphones.

When two amplifiers of the same kind are fed one into the other, they are said to be connected in

cascade. The whole arrangement is called an audio or R.F. amplifier, according to the frequencies it has to amplify, and each valve is called a **stage** of amplification.

There is one other possible arrangement of three valves, in which the first is an R.F. amplifier, the second is the detector, and the third is an audio amplifier. One very common arrangement of valves in the days when all valves were run from batteries was a five-valve set comprising two R.F. stages, the detector, and two audio stages.

Sets such as we have been describing are usually called "straight" sets, to distinguish them from **superheterodynes.** This is not the appropriate point at which to discuss this type of set, which is rather too advanced for us to tackle until we have a good practical knowledge of "straight" sets, but the superhet. is a receiver in which all signals are converted to a single frequency called the **intermediate frequency** before most of the amplification is done. This system of reception has so many advantages over simple detectors or even large "straight" sets that at least 90 per cent. of all receivers built to-day employ the superhet. principle. However, apart from the stage called the **frequency converter** or **frequency changer,** which is found in all superhets., these sets use amplifiers in exactly the same way as do straight sets, so that the latter, which are comparatively simple in principle and easy to build in practice, form a most necessary introduction to the superhet., which is the most important of all receivers.

REGENERATION AND REGENERATIVE SETS

Now to get back to things that are nearer home, as it were, we must say something about the principle of regeneration, and to do this we must go back to the way a tuned circuit works, which was described in an earlier instalment.

It will be remembered that a tuned circuit is able to amplify radio frequency currents that are fed into it, in such a way that it feeds a larger signal to the detector than could the aerial alone. Now the coil which is a part of any tuned circuit is wound from copper wire, and although copper is a very good conductor of electricity it still has a quite definite amount of resistance. When we wind a coil, we take steps to see that it has as little resistance as possible, because the greater its resistance, the less amplification will the coil possess. If it were possible to wind a coil which had no resistance at all, its amplification would be infinitely great, but such a coil is impossible to make. Coils can easily be made to give amplifications of between 50 and 300 times and in special cases, even more.

However, owing to the extremely minute voltages of the R.F. signals produced for us by the aerial, coil amplifications of this order are not enough to enable a straightforward grid-leak detector to give a loud signal in the headphones. The principle of regeneration enables us to use an ordinary coil with an amplification of 100 to 200 in such a way that we get the same result as if the coil had an amplification of 10,000 or more! With this amount of amplification we are really getting somewhere, for supposing that a signal of 1/10 volt is enough to make a recognisable sound in the headphones, this amount of amplification would allow us to hear an R.F. signal of only 1/100,000 volt, or 10 millionths of a volt. When it is realised that the big short-wave transmitters of the B.B.C. put in a signal in New Zealand that is much larger than this, one can easily see how it is that a one-valve set will pick up signals from right across the world.

HOW IT IS DONE

In Fig. 28 we have the circuit of a simple detector with regeneration, or a **regenerative detector** as it is more often called. If you examine this circuit carefully, and compare it with Fig. 27, you will see that there is very little difference indeed between the two

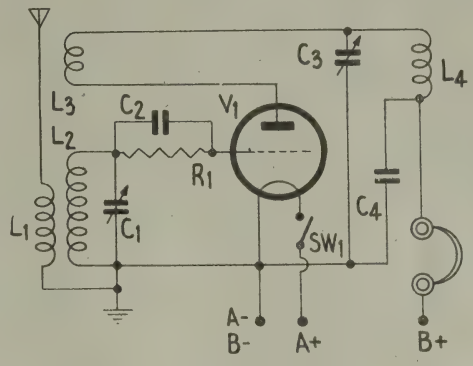


Fig. 28.

circuits. The important thing to note is the extra coil L_3, which causes the regeneration. L_3 is a third winding, on the same former as supports L_1 and L_2, and is a coil of comparatively few turns, quite closely coupled to L_2. When we were talking about aerial coils we told how currents flowing in the aerial coil cause or **induce** currents to flow in the tuned circuit coil to which it is **coupled** by placing the two windings close together. Well exactly the same state of

(Continued on page 55.)

FOR THE SERVICEMAN

This month we present the circuit of the Akrad Radio Corporation De Luxe Radiogram, Model 1467. Brief technical details follow.

(1) Wave-bands:

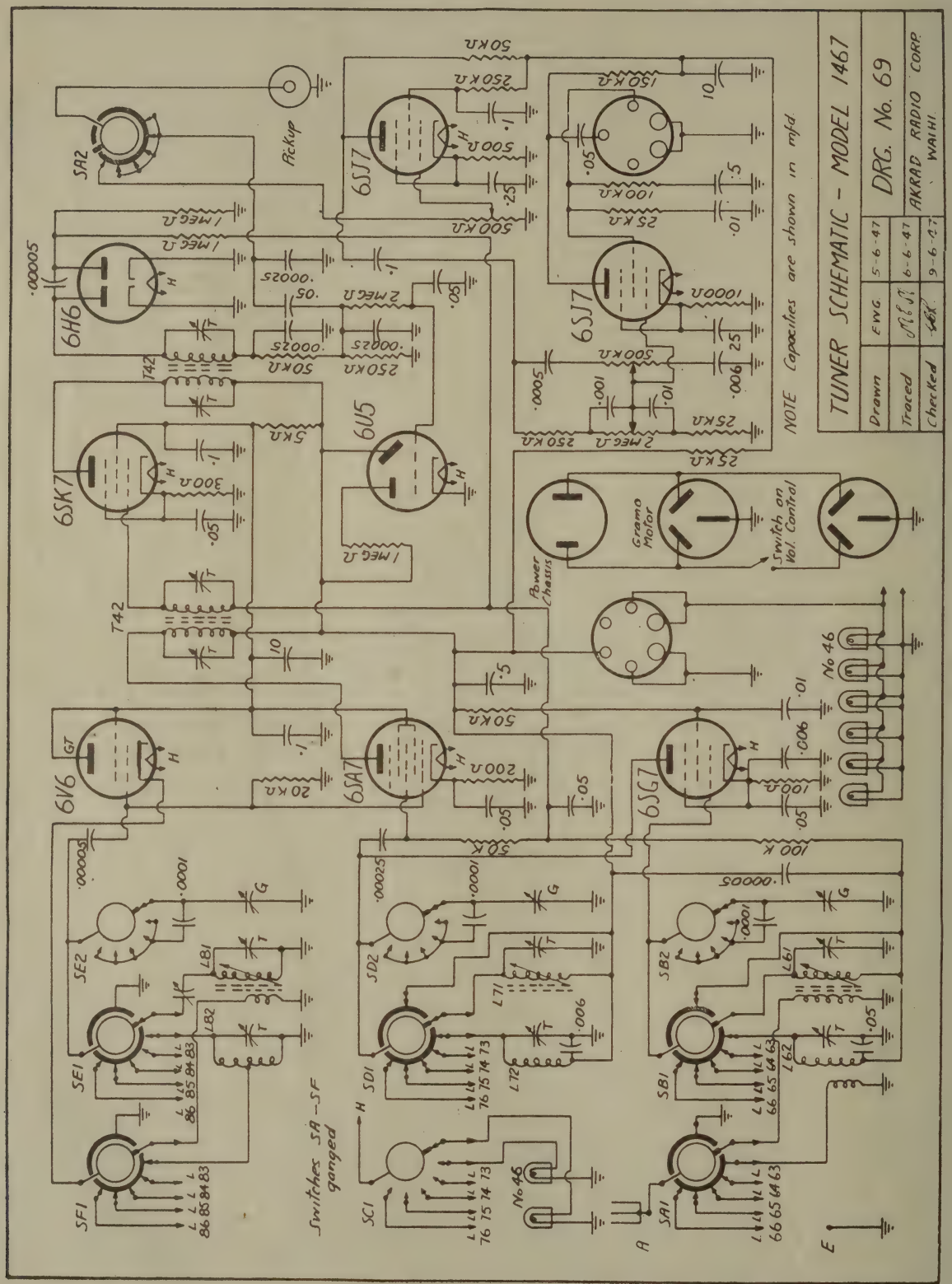
520-1650 kc/sec.
3.5-5.5 mc/sec.
5.5-8.5 ,,
8.5-13.5 ,,
13.5-20 ,,
20-31 ,,

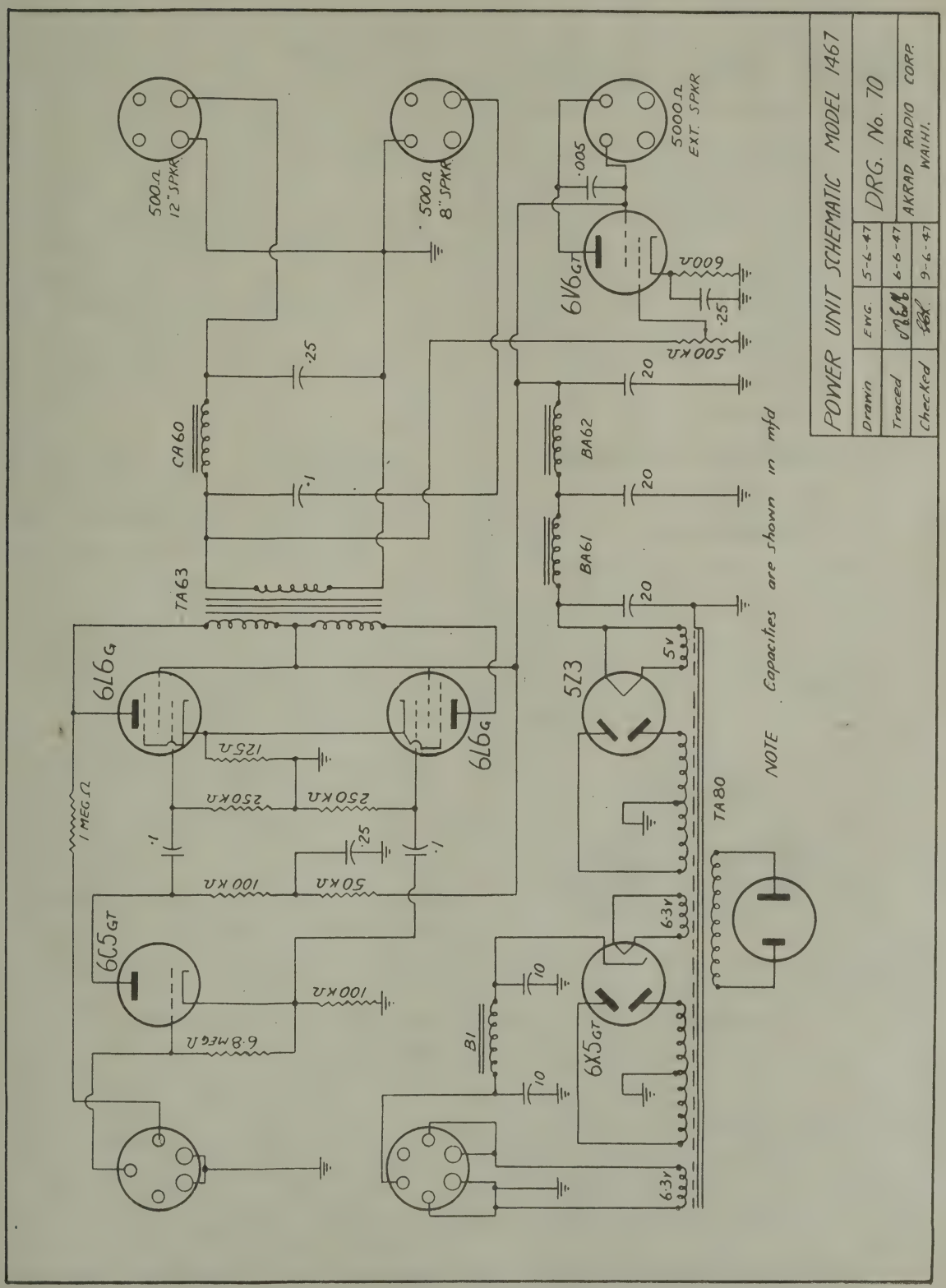
(2) Construction:

Two chassis are used, one containing the power supplies and output stages, and the other the tuner and voltage amplifier stages. Two speakers, 12 in. and 8 in. respectively. Automatic record changer.

(3) Circuit:

High-gain R.F. stage using type 6SG7 converter, 6SA7, and separate 6V6GT local oscillator. 6SK7 I.F. stage, 6H6 second detector and A.V.C. tube. 6SJ7 audio amplifier, to which are attached independent bass and treble controls. 6SJ7 voltage amplifier. On the second chassis are 6C5 phase converter, push-pull 6V6 output stage, and separate 6V6 output stage for feeding a separate extension speaker. The latter has its own independent volume control. Dividing network with cross-over frequency of 1600 c/sec. feeding 12 in. low-frequency speaker and 8 in. high-frequency speakers, for circuits see following pages.


TUNER SCHEMATIC - MODEL 1467
DRG. No. 69
AKRAD RADIO CORP. WAIHI
Drawn EVG 5-6-47
Traced MJ 6-6-47
Checked 9-6-47
NOTE Capacities are shown in mfd
6H6
6SK7
6V6 GT
6U5
6SA7
6SJ7
6SJ7
6SG7
Pickup
Gramo Motor
Switch on Vol. Control
Power Chassis
Switches SA-SF ganged
No 46
No 46
T42
T42
L42
L81
L82
L71
L72
L61
L62
SA1
SA2
SB1
SB2
SC1
SD1
SD2
SE1
SE2
SF1


POWER UNIT SCHEMATIC MODEL 1467
Drawn EMG. 5-6-47
Traced 6-6-47
Checked 9-6-47
DRG. No. 70
AKRAD RADIO CORP. WAIHI.
NOTE Capacities are shown in mfd
500Ω 12" SPKR
500Ω 8" SPKR
5000Ω EXT. SPKR
CA60
TA63
BA62
BA61
TA80
B1
6V6GT
6X5GT
6C5GT
6Y6G
6Y6G
523
.005
.25
.1
20
600Ω
500KΩ
125Ω
250KΩ
250KΩ
100KΩ
50KΩ
100KΩ
1MEGΩ
6.8MEGΩ
10
10
5V
6.3V
6.3V

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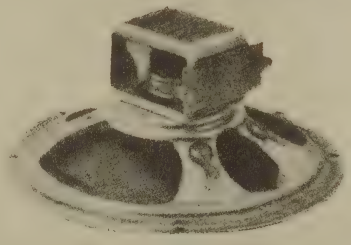

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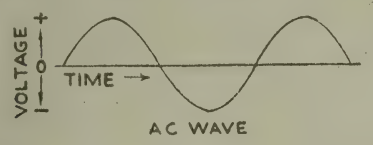
A PRACTICAL ANALYSIS OF ULTRA HIGH FREQUENCY TRANSMISSION LINES, RESONANT SECTIONS, RESONANT CAVITIES AND WAVE GUIDES

By J. R. MEAGHER and H. J. MARKLEY, R.C.A. Service Company Inc.

PART V

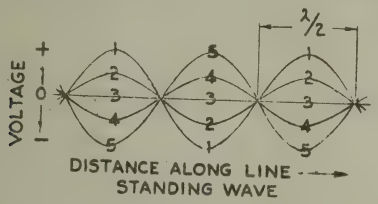
ADDITIONAL DATA ON STANDING WAVES

An A.C. wave may be drawn as a change in *voltage* during a period of time, as shown below.



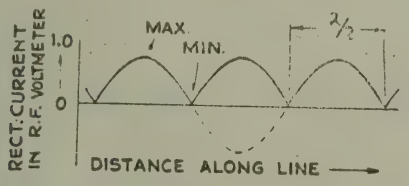
A standing wave is not as easy to show, because it involves changes in *voltage* with *time*, and with *distance* along the line.

The voltage between node points of a standing wave changes from positive to negative values and back during the time equivalent to one cycle of the R.F. source. This R.F. change in voltage is roughly indicated by curves 1 to 5 and back in the following sketch.



At some instant, the voltage along the line may be shown by one of these curves. It will be noted that the term "standing" wave can be misinterpreted. In a standing wave the *position* of max. and min. points does stand still, but the voltage changes at the R.F. rate.

When an R.F. voltmeter is moved along the line, it indicates the relative amplitude of the R.F. voltage variation at each point along the line. The rectified R.F. current in the meter circuit may be zero at nodes, and increases to a max. when the R.F. voltmeter is moved to each voltage max. point. Thus the *measured* standing wave appears as shown below. (This is a sine wave with the negative half-cycles "flopped up.")

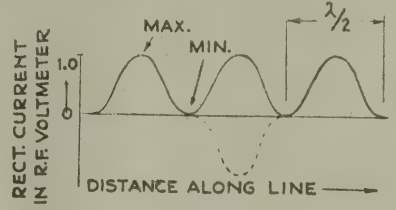


By turning one of the half-cycles down, as shown in dotted lines, it will be seen that the curve is a sine wave.

The standing wave that exists on the line is a sine wave, providing the R.F. source is sine wave; that is, a fundamental frequency with no harmonics. For slotted-line measurements, the generator must furnish sine wave output. If harmonics are present, some of the min. points, with the line open or shorted will not be zero.

If the standing wave on the line is sine wave, the *measured* standing wave will be sine wave, providing the R.F. voltmeter is *linear*.

If the rectifier in the R.F. voltmeter is not linear, the measured standing wave will not be sine wave, but will appear as shown.



By turning one of the half-cycles down, as shown in doted lines, it will be seen that the standing wave, as measured with a non-linear detector, is far from being a sine wave.

It will be noted that with a non-linear detector, the voltage min. points are not as "sharp" as indicated in the preceding illustration, which shows a standing wave measured with a linear detector.

The above graph shows how a non-linear detector introduces distortion in measuring a sine wave standing wave.

This non-linearity causes error in measuring standing wave ratios. In some applications of the slotted line, as for example when adjusting an antenna to "match" the line, this error may be ignored.

In other applications where it is necessary to determine the standing wave ratio accurately, correction can be determined in this way:

(1) Plot the standing wave as measured with the *particular detector* at the *desired frequency*, with the line open or shorted, and with the generator output adjusted for exactly full-scale deflection at the max. voltage points.

(2) Construct a sine wave (half-cycle) on top of the measured standing wave, with zero and max. points coinciding.

The sine wave indicates the current that would flow if the detector were linear.

Assume that a particular load produces a standing wave with a measured ratio of

$$\frac{\text{VOLTAGE MIN.}}{\text{VOLTAGE MAX.}} = \frac{0.21}{0.6} = 0.35$$

Reference to the curve shows that the value of 0.21 on the *measured* curve corresponds to 0.39 on the sine wave curve.

Also the value of 0.6 on the measured curve corresponds to 0.71 on the sine wave curve. The corrected standing wave ratio is therefore

$$\frac{0.39}{0.71} = 0.55 \text{ (instead of 0.35).}$$

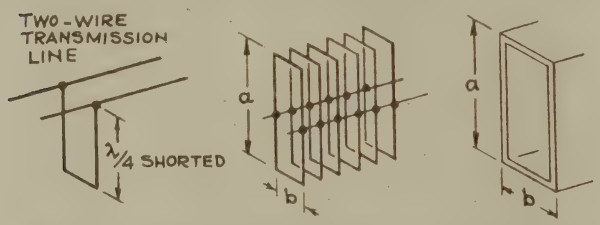
WAVE GUIDES

A wave guide is a simple hollow metal tube having no central conductor. The losses are relatively low, since they will be produced mainly by the "inner skin" of the tube (which is of large perimeter and hence gives low loss). The *inner surface* should be clean and smooth. The *outer surface* can be grounded at any point since the R.F. penetrates only a thin skin of the inner surface. *Sharp bends* are usually avoided, and all bends and twists are arranged to prevent a change in "mode" of propagation, or reflections. Instead of a hollow metal guide, a *solid dielectric* may be used as a wave guide. The action in this case is comparable to light waves travelling inside a *lucite rod*. In general, the loss in a solid dielectric wave guide is greater than in a hollow wave guide.

A wave guide cannot be conveniently treated like an ordinary transmission line. Wave guides must be approached from the viewpoint of an electro-magnetic wave in a dielectric, using the same basis of treatment as that of radiation.

Wave guides may be rectangular, round, or oval. At the present time, rectangular wave guides are most simple and common; this discussion will refer to rectangular wave guides for the most part, but much of this information can be extended to guides of other shapes.

The following development of a simple type wave guide is intended to serve as a means of bridging the gap between transmission lines and wave guides, although they operate on different principles.



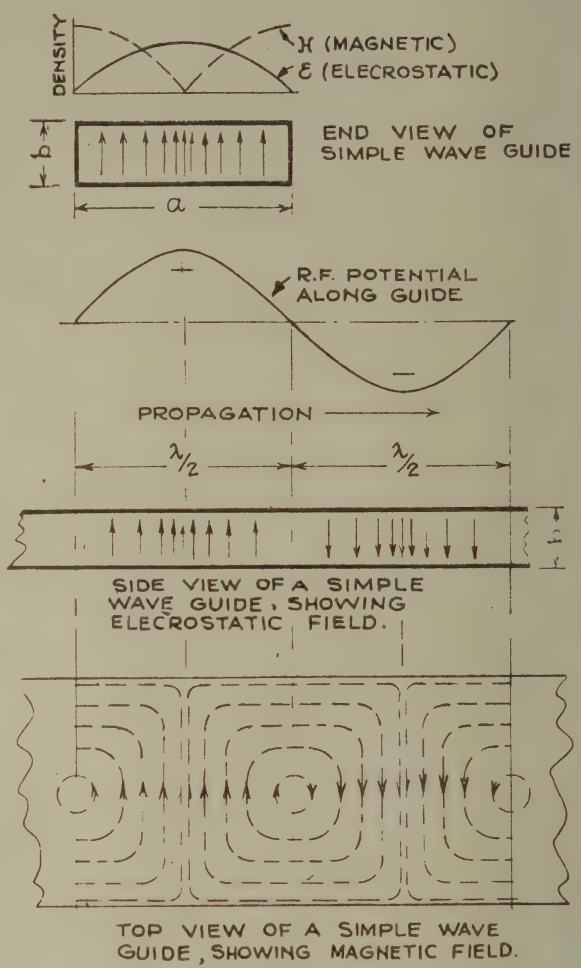
Above at left is shown a section of two-wire transmission line. A quarter-wave resonant stub has been added across the line. The ends of the stub where connected to the transmission line, will represent a high impedance—many times higher than the impedance of any practical two-wire transmission line. As a result the stub will have a negligible effect.

Suppose an infinite number of quarter-wave shorted stubs are added, resulting in a continuous pipe of rectangular cross section or one type of wave guide. See illustration above.

"a" has a minimum dimension of half a wave-length (in order to propagate a signal) but it may be greater. The "cut-off" frequency depends on dimension "a."

"b" is not critical except for voltage breakdown or the possibility of operation in a wrong "mode."

For a simple rectangular wave-guide, the electrostatic lines of force and density of distribution of the E. and H. fields are shown in the illustration. The electro-magnetic lines of force may be thought of as "whirlpools" in a plane, perpendicular to the electro-static lines of force, travelling down the tube in the direction of propagation. A rectangular wave-guide will transmit satisfactorily if the component of the electric field tangent to the side surface is zero at every point on the surface.



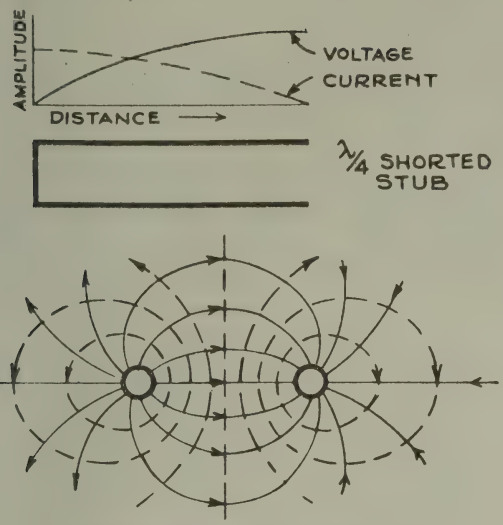
WAVE-GUIDE FIELDS

A two-wire and a co-axial transmission line are shown with the magnetic and electro-static fields indicated. A transmission line may be thought of as a guide for magnetic and electro-static fields.

TYPES OF PROPAGATION

"TM" propagation refers to *transverse-magnetic*, and is applied to the fact there is no magnetic field (H) in the direction of propagation down the tube. The electric field (E) does have a longitudinal component in the direction of propagation. There are numerous modes of operation (or oscillation) depending upon the cross section of the hollow metal tube and how it is excited from the R.F. source. Different modes of operation are identified by sub-numerals after the letters "TM."

"TE" propagation refers to *transverse electrostatic*, and is applied to the fact that the magnetic (H) field is in the direction of propagation and the electric (E) field is transverse. There are numerous modes of operation, identified as mentioned in the paragraph above. It may be of interest to note that "TEo" mode has the lowest "cut off" frequency of any that can be transmitted through a given tube. The fields shown in this article are TEo-1.



FIELDS ABOUT TWO-WIRE LINE

FIELDS IN A CO-AXIAL LINE

– – – – H OR MAGNETIC FIELD DUE TO CURRENT IN CONDUCTOR

——— E OR ELECTROSTATIC FIELD DUE TO VOLTAGE BETWEEN CONDUCTORS.

TRANSMISSION LINE FIELDS

TRANSMISSION OF R.F. ENERGY IN WAVE GUIDES

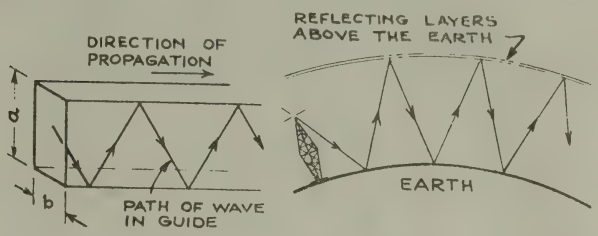
Electro-magnetic fields may be propagated down a hollow metal tube provided:

(1) The frequency is high enough.

(2) The fields have certain definite distributions.

Wave-guides are essentially ultra-high frequency devices since the frequency must be high before a field can be transmitted (from a practical point of view) through a wave-guide. A wave-guide has a definite cut-off frequency, as determined by the cross section of the hollow tube, and will not operate at a frequency lower than the cut-off frequency. When the guide is half a wave-length in width (dimension "a") the wave reflects back and forth across the guide making no progress at all (hence cut-off frequency). It may be considered that the wave-length of the R.F. energy must be short enough to fit into the cross-sectional dimensions of the wave-guide.

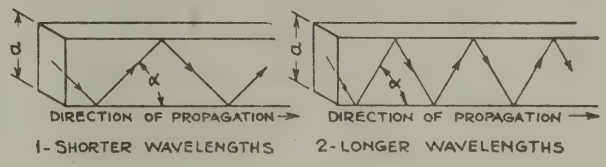
The velocity of propagation (group velocity) of R.F. energy in a wave-guide is *slower* than the speed in air. This is due to the fact that the wave does not travel straight through the guide, but is reflected from wall to wall. The length of the path that the wave travels is longer than the actual length of the guide. This action is comparable to the reflection of radio waves by ionized layers above the earth as illustrated.



The group velocity is dependent on the frequency and the tube dimensions (dimension "a" in a rectangular guide). For a given size of rectangular guide, the group velocity—

(1) Increases as the wave-length becomes shorter since there are fewer reflections from the wave-guide walls for a given amount of forward travel (see illustration "1") but is always less than the speed of light.

(2) Decreases as the wave-length becomes longer (up to the cut-off frequency) since there are more reflections from the wave-guide walls for a given amount of forward travel (see illustration "2").

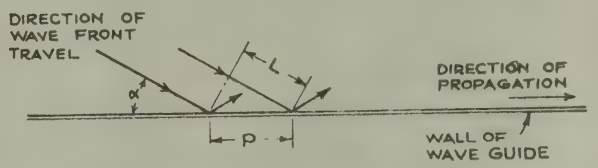


Phase Velocity (apparent speed) is greater than the speed of propagation; or the speed of travel in an unrestricted medium.

Apparent speed =

$$\frac{\text{(true speed)}}{(\cos \alpha \text{ between wall and direction of travel)}}.$$

Thus the apparent speed is greater since the waves are striking the wall at an angle.



In the time required for the wave front to move the distance "L," the point of reflection has moved the greater distance "P." Thus the apparent speed (phase velocity) is greater than the true velocity of propagation.

The wave-length in a hollow wave-guide (as measured on a slotted wave-guide) is always greater than, or at the limit equal to, the wave-length in air.

Attenuation in a rectangular wave-guide of given size varies as follows:

(1) As the wavelength of the signal increases toward the cut-off value, the attenuation increases since there are more reflections resulting in higher losses due to R.F. currents in the "skin" of the inside wall.

(2) At a much shorter wave-length, attenuation again increases due to increased "skin effect" at higher frequencies (except in a special case where the

electro-static field does not terminate on the wall of the guide).

(3) There is an optimum frequency of least attenuation; however, this is usually not used because of economy reasons.

The characteristic impedance is different for every mode of *operation.* In a round wave-guide the lowest characteristic impedance is about 350 ohms. In a rectangular wave-guide the characteristic impedance may be any value, as both dimensions are varied. The impedance is directly proportional to the narrow dimension "b," and if the other dimension "a" and the frequency are fixed, the impedance may be any value between approximately 0 and 465 ohms. The impedance approaches zero as the narrow dimension "b" is reduced.

The "Q" of a wave-guide is a function of frequency. It is also directly proportional to the ratio of volume to inside area of the guide. "Q" may be of the order of 25,000.

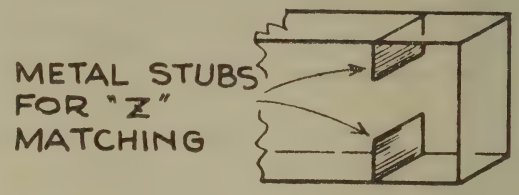
PRACTICAL FACTS ABOUT WAVE GUIDES

(1) An electrical quarter-wave length or odd multiples of a quarter-wave length, wave-guide *shorted,* reflects an *"opening"* where it joins another wave-guide.

(2) An electrical half-wave or multiples of a half-wave *shorted* reflects a "solid wall" where it joins another wave-guide.

(3) A quarter-wave section of wave-guide inverts the impedance as with ordinary forms of transmission line.

(4) A wave-guide has a "characteristic impedance" which is usually rather high compared with the impedance of co-axial lines.



(5) Impedance matching may be accomplished by using "shorting stubs." For instance, in matching to a dipole radiator. The stubs constrict the opening; may be used to "filter" out certain modes of operation.

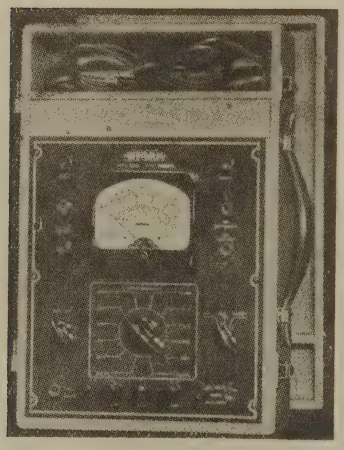
(6) Usually, where two wave-guide sections are joined in such a fashion as to be quickly removable, an R.F. choke is used.

An acoustic analogy (RCA "Tone Guard") is shown above. The slots around the inside of the cabinet act as chokes to prevent undesired high-frequency sound (that is, radiated by the vibrating parts of the phonograph pick-up) from "getting out" through the normal gap between the lid and the cabinet.

NOW AVAILABLE— The Latest

STARK TEST EQUIPMENT

MULTI-METERS, TUBE CHECKERS and INDIVIDUAL METERS



More than 30 years of experience have gone into the design, manufacture and assembly of Stark highest accuracy electrical instrument mechanisms. Built to precise standards, Stark Meters are critically examined at every step and individually calibrated against precision standard equipment.

Here we feature Model KM DE LUXE MULTI-METER—20,000 OHMS PER VOLT. Makes provision for voltage, current and resistance measurements in a total of 32 RANGES.

FIVE DC VOLTAGE RANGES AT 20,000 OHMS PER VOLT—2.5, 10, 50, 250, 1000.

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FIVE OUTPUT METER RANGES—2.5, 10, 50, 250, 1000. A.C. volts.

FIVE DB RANGES— −18 to +3, −6 to +15, +8 to +29, +22 to +43, +34 to +55.

FOUR OHMETER RANGES—4,000, 40,000, 400,000 ohms, 40 megohms.

FOUR MILLIAMPERE RANGES—1, 10, 100, 500.

ONE MICROAMPERE RANGE—100.

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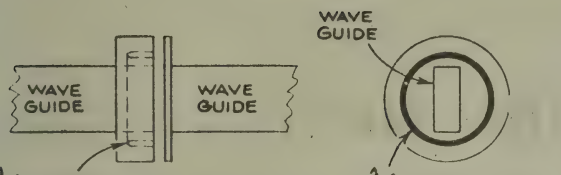
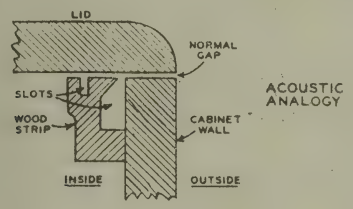

WAVE GUIDE
WAVE GUIDE
WAVE GUIDE
λ/4 DEEP SLOT (CLOSED AT BOTTOM) ACTS AS R.F. CHOKE FOR R.F. SIGNAL WHICH MIGHT TRY TO "GET OUT" IN A DIRECTION PERPENDICULAR TO THE AXIS OF WAVE GUIDE.
λ/4 DEEP SLOT MILLED IN CIRCULAR PIECE OF METAL BRAZED TO WAVE GUIDE.



(To be continued.)

The War Assets Realisation Board, Private Bag, Lambton Quay P.O., Wellington, has for disposal the following Z.C.1 Component Parts:

A143—Lids Carrying Case — ideal for chassis, steel, heavily copper plated, rolled edges, braced corners. Dimensions: 21" x 9" x 2¼"	2/6 ea.
GA200—Morse Key and Plug Assembly	5/– ea.
GA300—Microphones, Dynamic, Hand No. 7 ..	12/6 ea.
GA301—Microphones, carbon, Hand No. 3 ..	5/– ea.
GA302—Receivers Headgear, Dynamic, 75 ohms	10/– pr.
GA303—Microphones, Carbon, Hand No. 8 ..	5/– ea.
L109-1—Ribbed Coil Formers, wound and tapped (aerial loading), 2" max. diameter ..	1/3 ea.
L112-1—Chokes, Low Tension R.F.	6d. ea.
S157—Relay, Transmitter - receiver change - over, 3-pole, double-throw, 12-volt operation ..	10/9 ea.
S158—Relay, Keying, 1-pole, double-throw, 12-volt operation	4/6 ea.
T116—Choke anode modulation with side-tone winding	1/9 ea.
T118/2T118—Transiormer, vibrator, 12-0-12 volt D.C. input; 400-0-400 volt output ..	5/– ea.
T119—Choke, power supply filter, 2.5 Henries, with no D.C.	1/9 ea.
CV4—Condensers, variable, midget, 5-35 mmfd. (approx. ½" stub shaft)	1/9 ea.
2 D126—2¼" Instrument Knob with 5 holes drilled through face. Not tapped for grub screw	6d. ea.
2 L104—Coil, Beat Frequency Oscillator, permeability tuned for 465 kc/s. I.F.'s mounted in 1 9/16" sq. x 2" copper, cadmium plated cans	1/– ea.
2 L107—Transmitter Master Oscillator Coils (2 frequency ranges)	1/– ea.
2 L108—Transmitter Driver Stage Coils (2 frequency ranges)	1/– ea.
2 L109-3—Choke R.F. 4 pies each of 300 turns of 40 S.W.G., D.S.C. copper wire on ¾" former. Inductance, 4.8 mH., 6.2 ohms	6d. ea.
2 L118—Choke Parasitic Suppression. 25 turns 28 S.W.G., D.S.C. copper wire on 5/32" diam. resistor blank	3d. ea.
2 RCH621—Chokes R.F. Line	1/– ea.
2 S165—Switches, wafer rotary, 3-pole, 2-position, stub shaft approx. ½"	1/– ea.
2 T119AU—Vibrator Power Supply Units for operation from 12-volt supply	50/– ea.

All above prices subject to 20 per cent. sales tax, quoted F.O.B./F.O.R., Wellington.

Send inquiries to

THE NATIONAL NEECO ELECTRICAL AND ENGINEERING COMPANY LIMITED

Auckland, Wellington, Christchurch, Dunedin, Hamilton, Wanganui, Hastings.

Unsurpassed in Ceramics

Manufactured by the
UNITED INSULATOR CO., LTD.
Surbiton, Surrey, England

MODEL 718A.

Limited Quantity of fully imported JENSEN A12 and M20 High Fidelity Auditorium Speakers Now Available.

THE NEW SHURE "VERSATEX"

A LOW-PRICED EXTRA PERFORMANCE MICROPHONE

GENERAL: Model 718A "Versatex" is an extremely versatile high-output diaphragm type crystal microphone. The "Versatex," the versatile crystal microphone, is suitable for placement on table top, desk top or other flat surface; it fits conveniently in the palm of the hand for use as a hand microphone; and it may be used on a conventional floor stand for home recording, public address systems and similar purposes. The "Versatex," the versatile crystal microphone has typical semi-directional properties. The crystal microphone is provided with a built-in protective resistor to give increased protection against radio frequency burn-outs when used with radio transmitters. The Model 718A "Versatex" is supplied with a 7-foot shielded plastic-jacketed cable.

APPLICATIONS:

The Model 718A "Versatex" has a frequency response of 60-8000 C.P.S. with a specially engineered voice response for maximum intelligibility. It is the ideal "Ham" microphone and is also very suitable for home recording low-cost P.A. systems, call systems and similar uses. The durable plastic case of the "Versatex" makes this microphone especially safe for use with amateur equipment. The cartridge unit is mounted in rubber to provide mechanical isolation from the case, so that the microphone may be handled or carried about without annoying mechanical noise pick-up.

INSTALLATION:

The Model 718A "Versatex" is designed for placement on a flat surface and also may be held or carried in the hand. The microphone is provided with a regular $\frac{5}{8}$"—27 thread for use on any floor stand. No other connections need be made except the cable connection to the amplifier. Shipping weight, $1\frac{1}{2}$ lb.

Model	Cable	Impedance	Output
718A	7 ft.	High Impedance	53 db. below 1 volt per bar

Full Particulars from:—

INTERNATIONAL RADIO CO. LTD.

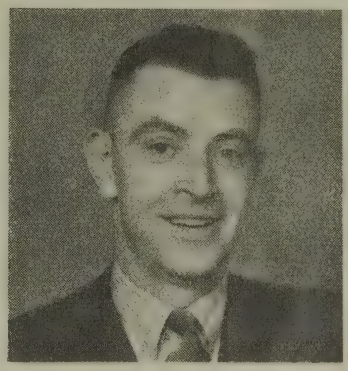
438 Queen Street, Auckland, New Zealand. Also at 254 Castlereagh St., Sydney, N.S.W., Australia.

OUR GOSSIP COLUMN

Founded in 1880 by the late Mr. F. J. W. Fear, the now well-known firm of F. J. W. Fear & Co., Ltd., first occupied premises in Willis Street, Wellington. It is interesting to note that, although the firm no longer occupies the original store, it has traded in Willis Street for almost 70 years.

Mr. Claude Fear.

Mr. S. Davison.



Mr. H. Bradbury.

In 1905 the present Managing Director, Mr. Claude Fear, joined his father—the business then being devoted entirely to sewing machines and cycles. In 1925, after a visit to England, Mr. Fear (Senior) was so impressed with the tremendous popularity of "wireless" that he decided to enter this promising field.

The first receivers to be imported were Browning Drakes and King Neutrodynes. In addition to complete receivers, components were the order of the day, and mainly consisted of three-coil tuners, valves (at 45/- each), and horn type loudspeakers.

Claude Fear very soon became an ardent enthusiast, and combining business with a useful hobby, devoted many hours each day to the assembly of kit-sets. In those days crystal receivers were very popular, and crystal "DX" was the all important achievement for the radio fan. Claude did much work on crystal sets, for this type of receiver represented a large percentage of business. He has had the unique experience of receiving 2FC and 2BL Sydney on a crystal set, and 5CL Adelaide and 4QG Brisbane with a crystal and two-valve audio amplifier!

Public reaction to radio was very mixed, and Claude recalls one experience when a set was sold in the store and instructions given for it to be installed at a private home in Wellington. Claude arrived at the house with the usual gadgets—A and B batteries, set, aerial gear and a horn speaker, etc., only to be confronted by the lady of the house who flatly refused to allow him to install it as she had been told on "reliable authority" that "wireless" sets attracted lightning!

Mr. F. J. W. Fear, who had been an active member of the firm until 1942, died in April this year at the age of 90. Upon his father's retirement from active business, Claude assumed control, and on the death of Mr. Fear (Senior) the business came under the control of the family, who admitted two new shareholders to the company—Syd Davison and Harry Bradbury, both of whom had been associated with Fears for some years. Claude Fear is now Managing Director, Syd Davison Manager, and Harry Bradbury Manager of the Radio Department.

Syd joined Fears in 1936, serving in the Army during the War and later with the Radio Development Laboratory before rejoining the Company in his present capacity.

Harry Bradbury has been with Fears for some years in charge of the technical and service department. In his new capacity, he is now well known among the radio fraternity, and frequently can be seen discussing, in his cheery way, the many problems confronting the radio home constructor.

* * *

Caught by the camera at the successful annual staff dance of National Electric, Wellington, are Ivan Cosgrave, Radio Manager, and Mrs. Cosgrave; Bob Donovan, Wellington Manager, and Mrs. Donovan; and Stan Shea of "Radio and Electronics" and Mrs. Shea.

In line with their general expansion programme, Dominion Radio and Electrical Corporation, Ltd., has appointed Mr. R. L. Grant as Service Manager for New Zealand.

In pre-war days, Bob was a dealer and serviceman in Taranaki, so that his personal experience in this field, and knowledge of the dealer "angle," will prove invaluable in his new appointment.

At the outbreak of war, Bob joined the R.N.Z.A.F. After a few months' service in this country, he was posted on attachment to the R.A.F. In Britain, following extensive study at Yatesbury, he specialised on radar, and gained considerable "operational" radar experience on the South Coast of England and, later, on the Continent. Returning to New Zealand after 3½ years overseas, he joined "Dreco" on his discharge from the Service.

From our personal knowledge of Bob's extensive experience and interest in dealer problems, we congratulate "Dreco" on this appointment and their far-sighted policy in maintaining close dealer-to-factory relations.

* * *

Mr. Noel Curtis, who is now London Director for Industrial Electronics, Ltd., arrived recently by air and will be making an extensive tour of New Zealand. In the course of an interesting trip Mr. Curtis spent 10 days in Calcutta, stopped over in Sourabaya and Singapore, and wound up with a week in Australia before reaching this country. Before the war Mr. Curtis was associated with Dominion Radio and Electrical Corp., Ltd., as designer and development engineer and was later sent by the New Zealand Government to the British Ministry of Production. In England he has had many interesting experiences linked with war-time development of Army communications. More recently he had a hand in the procurement on behalf of the New Zealand Government, of German and other machinery for shipment to New Zealand.

Industrial Electronics, Ltd., are interested in all forms of communication systems, instruments and the application of electronics generally to industry. Mr. Curtis will return to England before the end of the year.

* * *

Arthur Bradley, Managing Director of Bradley's Electrical Co., Wellington, accompanied by Mrs. Bradley, has been on a holiday and business tour of Australia for the past eight weeks. The first three weeks were spent on holiday, whilst Arthur devoted the remainder of the time to general business, which, judging from the smile on his face, was good. Welcome home, Arthur!

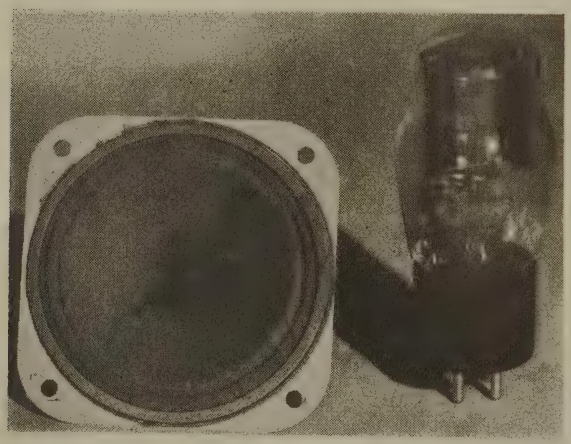
* * *

Mr. Les Hepburn, an ex-Air Force Radar Officer, has just purchased Tricity House, Christchurch. On leaving the Air Force, Les took over the service portion of Tricity House, while Nelson Tillman owned the retail side of the business. Recently, Nelson relinquished his interest, leaving Les in sole command.

FOR EXTREME SENSITIVITY—USE

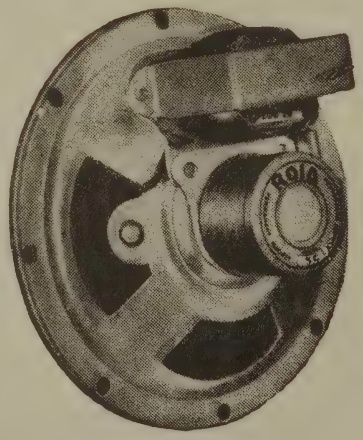
ROLA PERMANENT MAGNET SPEAKER

WITH THE NEW MAGNET ALLOY, ANISOTROPIC ALNICO.



ROLA 3C

Rola's smallest loudspeaker. Admirably suited for use in small portables and compact communication systems. A triumph in speaker design achieved by the use of Anisotropic Alnico. 29/9



ROLA 5C

A 5 in. 12-oz. speaker ideally suited for A.C. and A.C./D.C. midget receivers, and also finds useful application in vibrator and battery - operated sets. 29/9

ROLA LOUD SPEAKERS with ANISOTROPIC ALNICO

SWAN ELECTRIC CO., LTD., AUCKLAND, WELLINGTON, CHRISTCHURCH

THE BEGINNERS' SUPERHET

PART II.—CONSTRUCTION

In Part I of this article, we described the superheterodyne principle with reference to the circuit of the "Beginners' Superhet.," which is reprinted here for convenience, together with circuit values. Here also is given the chassis diagram, which, in conjunction with the front-cover picture of our November issue, shows just how the parts are mounted. From the photograph it can readily be seen which of the 1⅛ in. holes are used for the valves and which for the plug-in coils. Looking at the top chassis view, the right-hand tube is the mixer, with its own tuned circuit mounted on one side of the shield partition, while on the other side are to be found the I.F. transformer, in the square can, the oscillator valve behind it, and the second detector and audio amplifier tube, the 1D8, to its left. Also in this half of the chassis are the oscillator coil and tuning condenser. The valve socket on the back of the chassis is for a plug to which the battery connections are made.

No special precautions are necessary in wiring the set up, since an I.F. amplifier stage has been omitted, and there is no possibility of undesired oscillations or of instability. This is the reason why the set was made so simple and comparatively insensitive, because the constructor is enabled to give all his energies to operating the set and to finding out the distinguishing features of a superhet. without having to worry about possible faults.

COIL CONNECTIONS

It is quite immaterial which pins of the coil sockets are used for which connections, as long as all coils are made in the same way. It is suggested that the following scheme of connections be used, and that each coil as it is made is labelled "Aerial" or "Osc.," to show which socket it should go into.

Aerial Coil—

Pin 1	Aerial
Pin 2	Grid
Pin 3	Bottom of grid coil
Pin 4	Bottom of aerial coil

Oscillator Coil—

Pin 1	Plate end of L_4 (top)
Pin 2	Grid (top of L_3)
Pin 3	Other end of L_4
Pin 4	Earth end of L_3

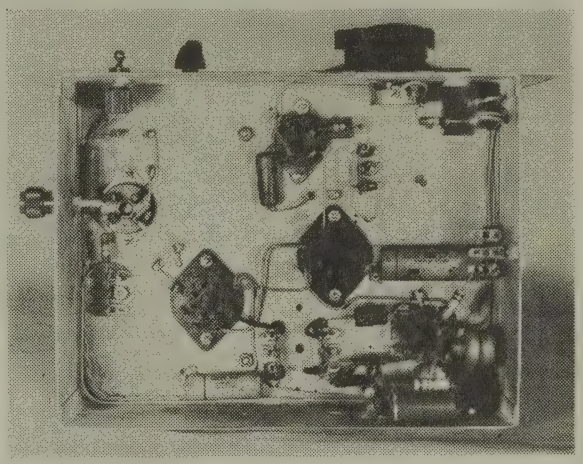
Note.—With these oscillator connections, the windings L_3 and L_4 must be wound in the same direction, in order to produce oscillation. If the connections to L_4 are reversed, V_3 will not oscillate.

These connections should be strictly adhered to, because, if both coils are connected in this way, no harm will come from plugging the oscillator coil into the aerial coil socket and vice versa. Different ways of connecting the two coils could result in such disasters as battery short-circuits if the coils became reversed in the sockets.

It will be noted that the oscillator tuning condenser C_9 is much smaller than C_2, the mixer grid tuning condenser. This is simply to shorten the frequency range covered by the oscillator coil and thus make tuning less tricky. The coils specified below give tuning ranges of 3 to 5 mc/sec. and 5 to 8.3 mc/sec., which is a good and sufficient slice of the shortwave bands for initial experimenting. The coils have been worked out in such a way that when the oscillator tuning condenser is fully closed, the mixer tuning condenser is about fully closed also, for correct tuning to the signal.

COIL-WINDING DATA

All coils are wound on 1¾ in. diameter cardboard former, mounted with glue on four-pin valve-base type of plugs. (These are the ones often sold with metal covers for use as cord connectors.)



Under chassis view of the receiver.

Aerials Coils:

Range A, 3-5 mc/sec.

L_2, 35 turns of 22-gauge D.C.C. close-wound.

L_1, 12 turns of 24-gauge en. close-wound in same direction as L_2, spaced ⅛ in. from bottom end of L_2.

Range B, 5-8.3 mc/sec.

L_2, 8¾ turns of 22-gauge D.C.C. spaced to occupy ¾ in. of winding space.

L_1, 4 turns of 24-gauge en. close-wound, ⅛ in. from bottom end of L_2.

Oscillator Coils:

Range A—

L_3, 45 turns of 24-gauge en., close-wound.

L_4, 11 turns, same wire, close-wound in same direction, 3/32 in. from bottom end of L_3.

Range B—

L_3, 16 turns of 22-gauge D.C.C. close-wound.

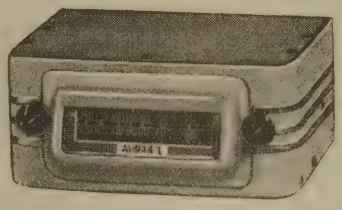
L_4, 5¼ turns of 24-gauge en., close-wound ⅛ in. from bottom end of L_3.

OPERATING THE SET

Since the second detector of this set is regenerative, with R_4 as the regeneration control, the first step in searching for a signal after the aerial has been connected is to advance R_4 until the familiar rushing sound of the oscillator detector can be heard. With this circuit, the regeneration control is very quiet,

and one has to listen carefully to ensure that the detector is oscillating. Having done this, the oscillator tuning condenser is turned full in, and the mixer tuning condenser likewise. Next, the oscillator condenser is turned gradually towards the low-capacity end of the scale, and a sharp look-out is kept for whistles, which are signals. As soon as one is heard, stop the oscillator condenser on the whistle and tune the mixer condenser C_2 until the signal is loudest. When this point has been reached, it means that the mixer grid circuit is tuned to the signal, and the oscillator is tuned to a frequency of signal + I.F., where "I.F." represents the frequency to which the I.F. transformer T_1 is tuned.

So far we have assumed that this has been correctly tuned to 465 kc/sec. by means of its trimmers, but this will not necessarily be so when the set is first wired up. This being an experimental set, it does not matter very much whether the I.F. is exactly 465 kc/sec. or not, so that proper alignment of the transformer is not important. All that needs to be done is to turn **one** of the trimmers, **leaving the other set** until, with the detector oscillating,



MADE BY
WEBBS RADIOS

The 'ARIEL'
1948 Model
6 Valve
Car Radio

Kit-sets Available.

- Designed to give radio reception in cars from any part of New Zealand at all times.
- Easily fitted into any make of car.
- Free from interference from ignition and other sources.

The set consists of two units, the Control Head and the Speaker Unit, joined by flexible cable.

THE CONTROL HEAD contains the volume control, tuning-knob, and easily-read etched glass slide-rule dial, sloping for greater visibility from the driving position. It is of small size, suitable for convenient mounting in any car, either under the dash panel, in a glove pocket, or in any position easily reached by the driver. Mounting is made easier by the fact that the Head is connected to the Speaker Unit by a completely flexible cable, which may be bent or twisted in any way. This allows greater freedom in choice of mounting position of both the Head and the Speaker.

THE SPEAKER UNIT is especially compact, its small size, 8¼ in. x 5¾ in. x 5¾ in., enabling it to fit easily on to the fire wall of any car, where it is held by a single mounting bolt. On its front panel is the continuously variable tone-control knob and power switch. The unit houses the power supply, I.F. and audio amplifiers, and P.M. speaker.

THE CIRCUIT consists of a 6SK7 tuned R.F. amplifying stage coupled by means of a special adjustable aerial matching system to any low-capacity car antenna, preferably of the vertical type. A 6SA7 mixer value gives low noise level conversion of the signal to intermediate frequency, which is fed down to the I.F. amplifier in the speaker unit.

Iron-cored I.F. transformers are used in conjunction with another 6SK7 valve to obtain maximum possible I.F. amplification. The 6Q7 and 6V6 valves form an efficient audio amplifier, and the permanent magnet speaker, by using no field excitation current, ensures lowest possible battery drain. This is about 5 amps. at 6 volts.

High-tension power is provided by a 6X5 rectifier valve, heavy duty 250-volt transformer, and a quiet, low-hash, non-synchronous vibrator. All traces of hash are eliminated by suitable chokes, by-pass condensers, and efficient cadmium-plated housings, and a resistance-capacity filter gives hum-free smoothing with no choke windings to corrode and burn out.

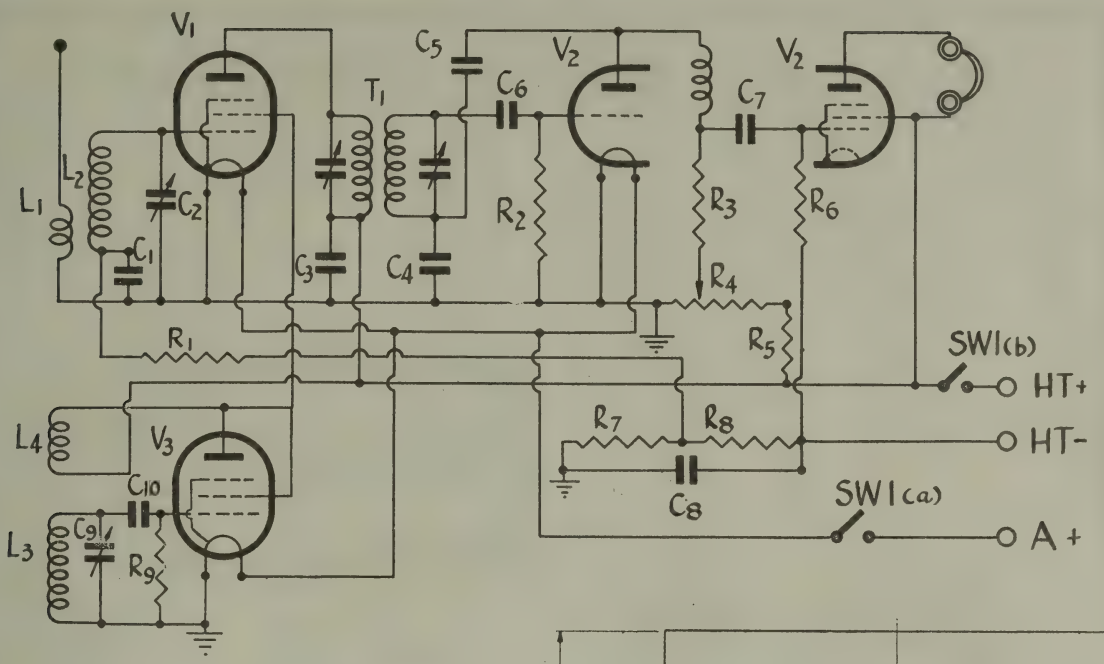
Spark interference is dealt with by the latest methods of suppression, both in the aerial circuit and the power input section. Extra large spark plate, double shielding, bonding of housings, etc., and low-pass aerial filter are all features which assist in preventing reception being marred by ignition and generator noises. Except in difficult cases, no spark plug suppressors are needed on the car itself, and these exceptions can usually be completely filtered by a single distributor suppressor or generator condenser.

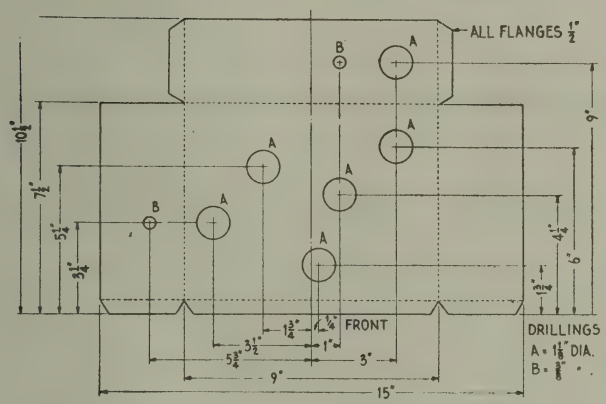
The two units are attractively finished in fine crackle, and the shaped cord speaker grille, and pressed-out celluloid dial bezel give the machine a neat overall appearance.

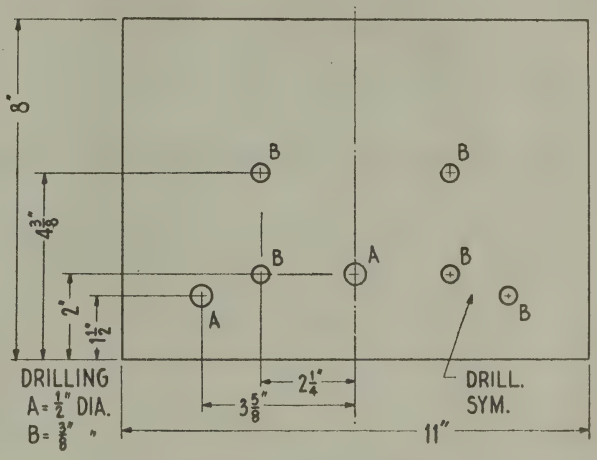
The KIT-SET is complete with all components for assembling the machine, soldering iron, pliers, and screwdriver being the only additional requirements. All metal work parts are punched to fit neatly into place, and the chassis shields, housings, etc., are cadmium-plated for good contact, easy soldering, and professional appearance.

Enquiries also invited from Servicemen and Dealers for completed radios or knock-down kit-sets.

WEBB'S Radios LIMITED
11 Wellesley St. E.
AUCKLAND







static or other interference can be heard. While doing this, it is best to have the low-frequency set of coils in place, and both tuning condensers set to maximum capacity. This procedure gives a sufficiently close adjustment of the T_1 trimmers for a signal to be picked up. When one has been found, the I.F. trimmer **in the plate circuit of V_1** should be tuned for the loudest signal.

OPERATING CHARACTERISTICS OF THE SET

When the first signals have been picked up, the tuning of the set can be tried. The best procedure at first is to tune the oscillator condenser only, and then bring the mixer condenser in line with it, as judged by maximum noise, or maximum signal if a new one has been found. After a while it will be noticed that, starting from the low-frequency end of the dial (condensers all in) and working towards the high-frequency end, the mixer condenser will be only half unmeshed (or thereabouts) when the oscillator condenser is fully unmeshed. This is because of the different values of C_2 and C_9, and is quite normal.

Some further characteristics of the set will be explained in the third and final part of this article.

(To be concluded.)

COMPONENT LIST

L_1 to L_4 and T_1, see text.
$C_1 = 0.01$ mfd.
$C_2 = 100$ mmfd. variable.
C_3, $C_7 = 0.05$ mfd.
$C_4 = 50$ mmfd.
$C_5 = 25$ mmfd.
C_6, $C_{10} = 100$ mmfd.
$C_8 = 25$ mfd. 25v.
$C_9 = 75$ mmfd. variable.
R_1, $R_5 = 50$k.
$R_2 = 2$ meg.
$R_3 = 100$k.
$R_4 = 25$k. pot.
$R_6 = 500$k.
$R_7 = 125$ ohms.
$R_8 = 1$k.
$R_9 = 25$k.
Sw_1 = D.P.S.T. switch.
$V_1 = 1$N5-GT.
$V_2 = 1$D8-GT.
$V_3 = 1$P5-GT.
R.F.C. (plate of $V_2 = 10$ mH. choke.

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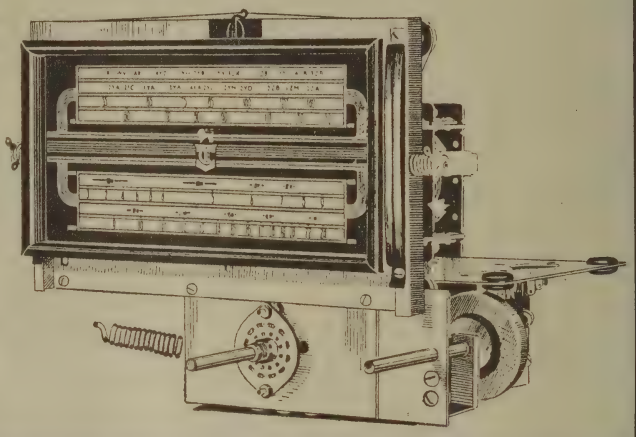

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NO. 2: 70 WATTS FROM EL37'S

As we remarked at the end of the first issue of the "Experimenter," we have had a large number of inquiries as to the exact method of obtaining 70 watts from a pair of EL37's. We are not surprised, because one of the more or less unexplained difficulties of tube application has always been to realise in practice the power output given by manufacturers in their concise data. First of all, it should be emphasized that in general such data are very accurate, and reproduction of the stated conditions will always allow the rated outputs to be obtained. This can only mean that failure to do so is through failure to reproduce the "stated conditions."

WHERE MEASURED

In the first place, tube data always means by the term "maximum power output," "maximum power output as measured at the plates of the valves"—**NOT** maximum power output at the secondary of an output or modulation transformer. The latter are usually a good deal less efficient than they are given credit for, with the result that loss in the transformer is blamed against the valves.

Secondly, when published data specify given electrode voltages, those voltages are assumed to be constant at all output levels. That is, the power supply is assumed to have perfect regulation—as in fact they have that are used to obtain the published figures.

Thus, the question of rated output from audio amplifier tubes is very much bound up with the design of the power supply, especially in class AB_2 or B_2 amplifiers. Some tubes specially designed for class AB_1 operation, as is the EL37, also require power supplies having good regulation, because of this unusually wide variation in cathode current from zero to full output.

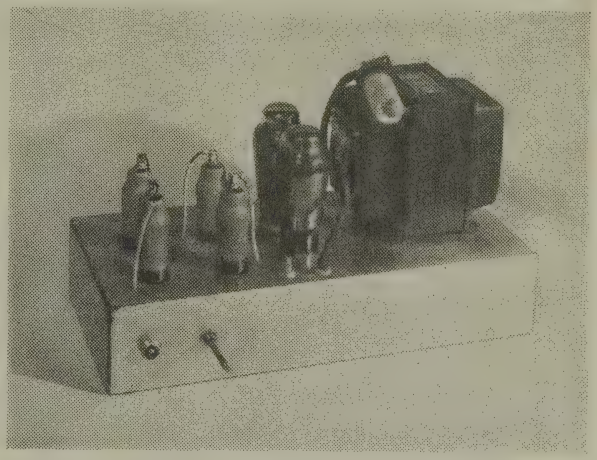
POWER SUPPLY CONSIDERATIONS

In the present case we have a pair of tubes designed to produce a large power output with only a comparatively low plate voltage, viz., 400v. maximum. This being the case, the current requirements for both plates and screens are quite high. This is inevitable, as it is impossible to get something for nothing, and watts input means either high voltage and low current, or low voltage and high current.

With the rated maximum of 400v. on plate and screen, a pair of EL37's take total screen and plate currents of 12 and 100 ma. respectively, at a bias of — 36 volts and with no input.

At full input, these figures rise to 72 and 276 ma. respectively. Thus if both screens and plates were to be fed from the same power transformer, it would have to handle 348 ma. on peaks—forgetting altogether about the consumption of the voltage amplifier stages. The zero signal current would be only 112 ma., so we have a fairly difficult power supply problem if the regulation is to be kept within reasonable bounds.

In order to avoid such a design it was decided to use two separate power transformers; one to supply the EL37 screens and the voltage stages, and the other to supply the EL37 plates only. This seems to be the easiest and best way of fulfilling the power supply requirements, and in the long run it is probably the cheapest as well. It is not necessary to provide very complete smoothing, both because of the push-pull connection and because of the high power level. Thus each power supply has been designed to use a single section choke-input filter. This gives adequate smoothing for the output stage, while an additional small choke (shown in the amplifier circuit) is used to give the added smoothing required for the voltage stages.

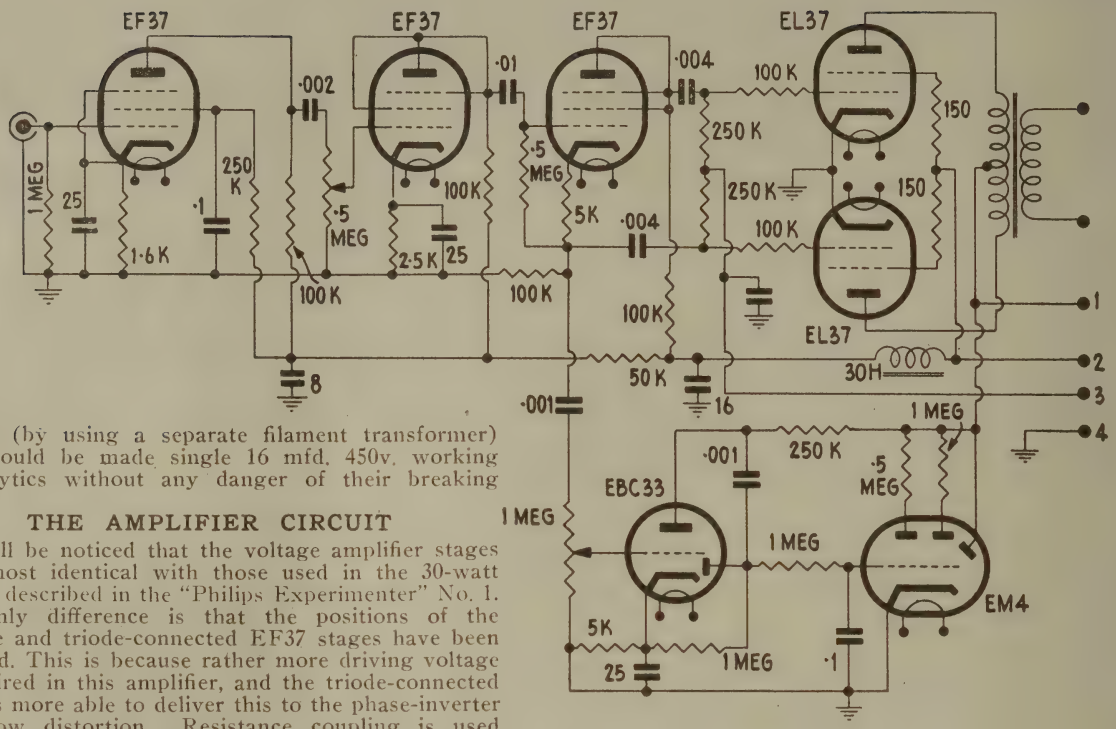


Choke input has been used because of its superior regulation, and because it is much kinder to the mercury vapour rectifiers which are also essential if the regulation is to be good enough.

The values specified in the list underneath the power-supply diagram are such as to give a regulation of approximately 3 per cent. for each supply. That is to say, at full load the supply voltages will not drop by more than 12 volts from the no load value of 400. This is quite satisfactory, as experiment has shown that full power output can be obtained with as little as 350 volts on plate and screen. This does not contradict our statement above, for with regulation as poor as this, the distortion at full output would be severe. A full-load voltage of 388 will enable the full power output to be obtained with little more than the 2.5 per cent. distortion quoted in the tabulated data.

The bleed resistors of 15,000 ohms are used to increase the load on the power supplies under no signal conditions and to act as protection in the event of their being turned on with no proper load connected.

The electrolytics have been specified as two 16 mfd. units in series for the sake of safety during the switching on period, but if arrangements are made to heat the amplifier heaters before the H.T. is



applied (by using a separate filament transformer) these could be made single 16 mfd. 450v. working electrolytics without any danger of their breaking down.

THE AMPLIFIER CIRCUIT

It will be noticed that the voltage amplifier stages are almost identical with those used in the 30-watt version described in the "Philips Experimenter" No. 1. The only difference is that the positions of the pentode and triode-connected EF37 stages have been reversed. This is because rather more driving voltage is required in this amplifier, and the triode-connected stage is more able to deliver this to the phase-inverter with low distortion. Resistance coupling is used throughout, since the EL37 even at full ratings are operated only in class AB_1, i.e., without grid current, so that a driver supplying signal power through a transformer is not required.

The same volume indicator circuit has been used as before.

The only notable difference between the two amplifiers is the fact that this time the EL37's are operated with fixed bias, from a battery. This is shown on the power supply diagram and gives 36 volts. It can be made from four 9-volt or two 18-volt "C" batteries in series, and will last a very long time, since no current is either drawn from it or passed through it.

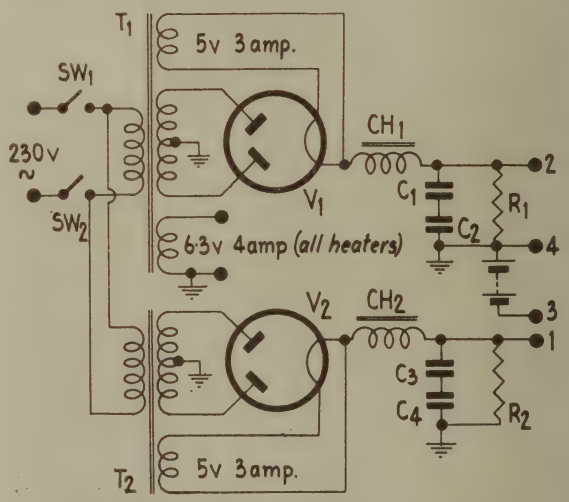
In case some should have any doubts, the high grid resistance of 350k. is quite in order, and causes no trouble whatever. The 100k. grid stoppers prevent the grids from going more than a fraction of a volt positive should the EL37's be over-driven.

OPERATION

If a suitable power supply is used such as the one recommended here, or any other supply with equally good characteristics, no difficulty will be experienced in realising the full rated output of 70 watts, measured from plate to plate. This gives ample leeway when the amplifier is to be used to modulate a class C R.F. stage with 100 watts input, for even if the modulation transformer is only 75 per cent. efficient, there will still be left 52½ watts—more than sufficient to do the job. Should it be found that the 150-ohm screen stoppers cause a little too much voltage drop, their value can be reduced to 50 ohms, but with the specified power supply this should not be necessary.

* * *

Next month's issue of the "Philips Experimenter" will contain a description of an ultra-modern "straight" receiver using the now famous Philips R.F. pentode the EF50 in all three stages—R.F., regenerative detector, and audio.



POWER SUPPLY COMPONENTS

V_1, V_2 = 83.

CH_1, CH_2 = 30H, 250 ma., 100 ohms.

T_1, T_2 = Power transformer, 490-0-490v. (see text).

R_1, R_2 = 15,000 ohms, 20 watt.

C_1, C_2, C_3, C_4 = 16 mfd. 450v. electro. Fig. 100 ma. and Fig. 250 ma. respectively.

Battery = 36v. bias for EL37's.

Note.—Terminal numbers correspond to numbers on amplifier circuit.

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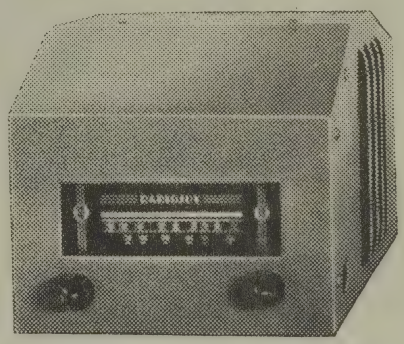

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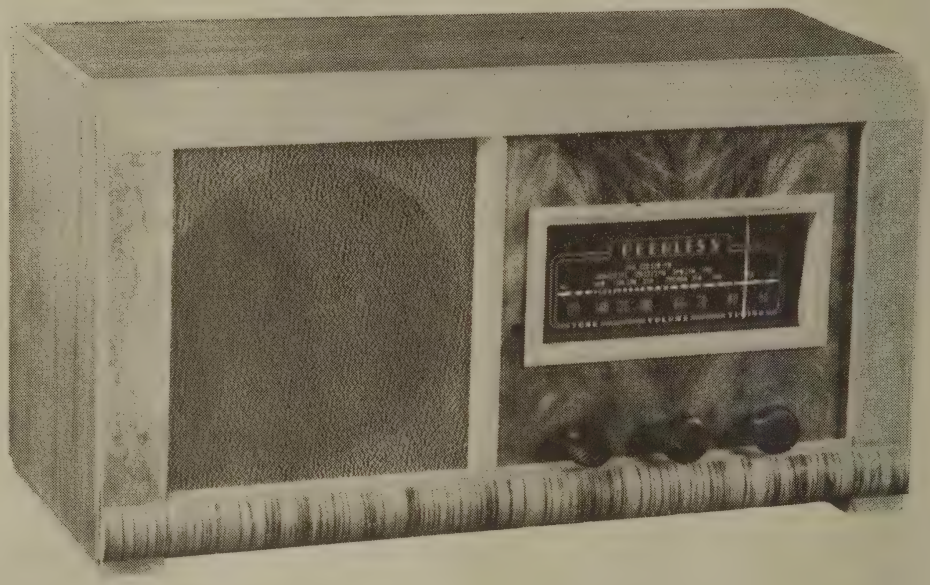

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ELECTRONICS IN METEOROLOGY

(Continued from page 6.)

hoped that adequate information has been given to enable readers to appreciate the problems in radiosonde design should any would-be experimenters wish to evolve new circuits or methods of transmission.

BEGINNERS' COURSE

(Continued from page 35.)

affairs exists with L_2 and L_3. The latter is connected in the plate circuit of the valve, so that the plate current must pass through it. Now since the valve acts as an amplifier, there is in the plate circuit an amplified version of the R.F. voltages which are applied to the grid. These amplified voltages cause R.F. currents to flow in L_3. Now since L_3 is coupled to L_2, these currents in turn cause new currents to flow in L_2. These **induced** currents are exactly similar to the original R.F. currents in L_2, and so add to them, causing larger currents to flow in L_2 than did before L_3 was introduced into the circuit. These larger currents cause a larger voltage to be found at the grid of the valve. The sum total effect is exactly the same as if no regeneration had been used, but instead a better coil with more amplification had replaced L_2. Another term commonly used to-day is **feedback,** which if applied in the right direction is called **positive feedback,** which is exactly the same thing as regeneration. The name feedback is more or less self-explanatory, as it indicates that currents in the plate or output circuit of the valve are fed back to the grid or input circuit.

In next month's instalment we will complete our description of the circuit of Fig. 28, and will also have something to say about making it work, for it is a perfectly practical circuit which can give excellent long-distance reception.

(To be continued.)

TRACKING OF PICK-UPS

(Continued from page 24.)

Thus we have

$$\frac{R^2 + A^2 - (A - d)^2}{2AR} - \frac{r^2 + A^2 - (A - d)^2}{2AR} = 0$$

Rearranging,

$$\frac{(R - r)(Rr - 2Ad + d^2)}{2ARr} = 0$$

The only significant case contained here is when

$$Rr - 2Ad + d^2 = 0$$

from which

$$d = A - \sqrt{A^2 - Rr} \quad . \quad . \quad . \quad . \quad (8)$$

The above equation gives the optimum value of d for a given record and arm radius.

Minimum Error with Fig. 3

Let R_{min} be the record radius at which minimum tracking error occurs.

Then from equation (7) we have that

$$\frac{R_{min}^2 + A^2 - (A - d)^2}{2AR_{min}}$$

must be a minimum.

Expanding this expression we get

$$\frac{R^2_{min} + 2Ad - d^2}{2AR_{min}}$$

must be a minimum, but $2Ad - d^2 = Rr$ from equation (8).

Thus

$$\frac{R^2_{min} + Rr.}{R_{min}}$$

must be a minimum.

Rearranging, and differentiating with respect to R_{min},

$$R_{min} = \sqrt{R.r.} \quad . \quad . \quad . \quad . \quad . \quad (9).$$

Thus, when R_{min} has been found, θT_{max} can be found by substituting R in equation (7) and θT_{min} may be found by substituting R_{min} in the same equation.

Then the required angle of offset is

$$\frac{\theta T_{max} - \theta T_{min}}{2}$$

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A SUPERHET. TRACKING CHART

(Continued from page 27.)

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ACCURACY OF APPLICATION

It should be realised that extraordinary accuracy cannot be obtained by means of these charts, nor is it intended that it should be. All that can be expected is enough accuracy for the calculated values to act as a guide to initial design, and for adjustment of trimmers and padder to do the rest.

SUPPRESSION OF INTERFERENCE

(Continued from page 32.)

Electro-medical apparatus and H.F. industrial heating plants invariably require total screening with filters in the power line. In the former case, it is essential that the patient must be inside the screened enclosure.

A very complex suppression problem which has been dealt with recently was that of the trains used on the Royal tour of the Union of South Africa. The Royal train and the pilot train presented two rather different problems. In the case of the former, the amount of interference-creating equipment was very large, whilst the number of filters which it was possible to instal was a minimum. Therefore, the suppression had to be achieved by the use of capacitors and the maximum amount of screening and bonding. The pilot train had rather less interference-creating equipment than the Royal train, and there was sufficient space to fit the necessary filters. On both trains, most of the telecommunications equipment and two-channel broadcast receiving equipment was installed inside the screened compartments with all supplies filtered.

CLASSIFICATION OF AMPLIFIERS

(Continued from page 16.)

fier it can be seen that if the fundamental definitions of class B and C amplifiers are granted, there is no possible justification for the introduction of this term. It is merely a first-class example of the kind of confusion we have been discussing. Since by definition there can be no sharp dividing-line between class B and class C, there can also be no such thing as a class BC amplifier. The term is intended to indicate a valve operating with a value of bias intermediate between the normal bias for class B and class C working and should be described as such, however convenient the term "class BC," for this name is definitely misleading.

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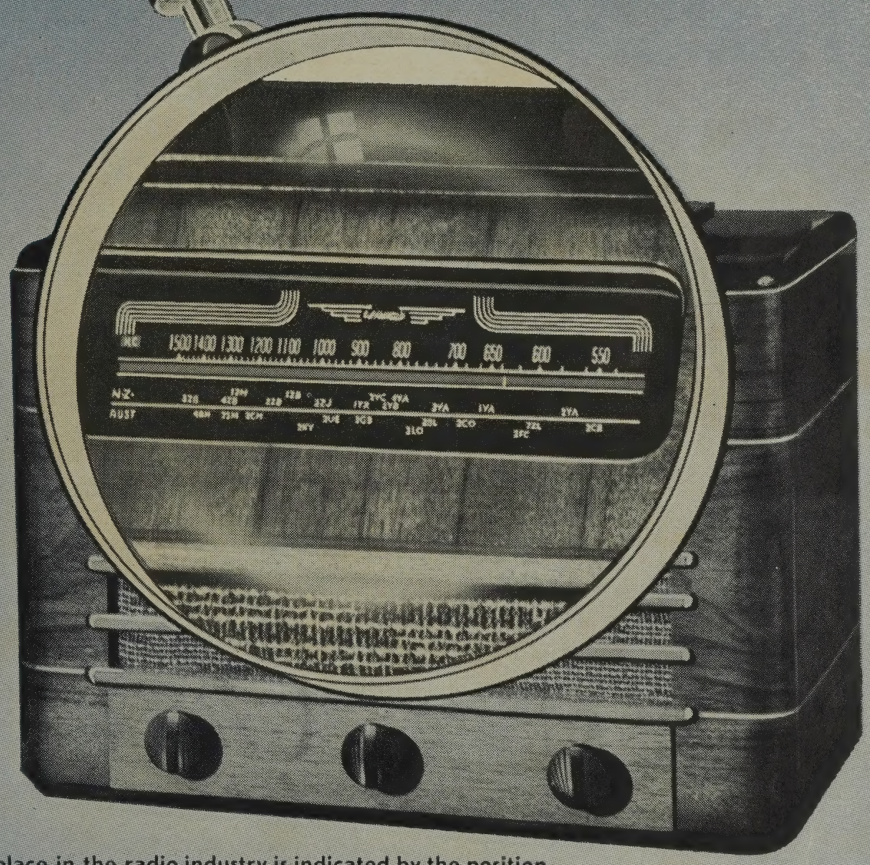

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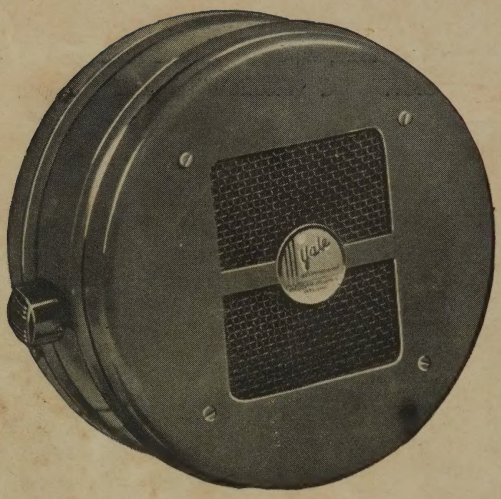

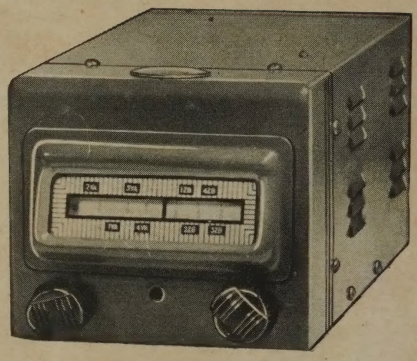

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